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A PRELIMINARY REPORT ON PRECIPITATION DATA 1968 – 1971, VENISON CREEK

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VENISON CREEK REPRESENTATIVE BASIN:
A PRELIMINARY REPORT
ON PRECIPITATION DATA
1968 - 1971

By

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PREFACE

As part of the Ministry of the Environment's contribution to the International Hydrological Decade program, the River Basin Research Section is carrying out studies of water resources and physical conditions in five basins in Southern Ontario. These basins were selected as being representative of common type areas in the Province and the hydrologic studies being undertaken are designed to provide a better understanding of most aspects of the water balance in these areas. The Venison Creek basin was selected as being representative of sand plain conditions in the southwestern portion of the Province.

This bulletin outlines the results of a preliminary analysis of precipitation data in the Venison Creek basin. The climatological network in the basin was installed with the assistance and co-operation of the Atmospheric Environment Service, Federal Department of the Environment. The analysis was undertaken to assess the effectiveness of the precipitation gauge network for determining reliable and representative estimates of precipitation events and accumulations. Such an analysis is a necessary prerequisite to the other hydrologic studies that require precipitation data as input.

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K. E. Symons, Director,
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Toronto, February 1, 1974.

TABLE OF CONTENTS

ABSTRACT

Sampling theory of normal distribution is used as a basis for the statistical analyses of precipitation data compiled for the period 1968 to 1971 in the Venison Creek IHD representative basin. The analyses provide for an evaluation of the existing precipitation gauge network.

Results of analyses for selected groups of areal average precipitation (daily, monthly and annual), are compared. The comparisons are used to show that the standard errors of average, based on the measurements of the areal extent of the precipitation events, tend to decrease with an increase in the amount of precipitation and to a lesser extent, with the lengthening of the accumulation period.

The extent of the uniformity in areal distribution of precipitation events is demonstrated through inter-station correlations and linear regressions between pairs of stations.

Empirical relationships between the standard error and areal average precipitation samples are used to supplement the theoretical projection of the size of the precipitation gauge network for desired sampling accuracies. Because of the existence of significant inter-station correlation, the network is further analysed and evaluated on the basis of reduced standard errors. The result of the analysis, using the reduced standard errors for the theoretical extension of the gauge network, produces a >50% reduction in the size of the network for the same degrees of accuracy.

The precipitation events in the study area are shown to be representative of those precipitation events in the general climatic region. This is demonstrated through lack of significant difference between averages and through high inter-station correlations.

The frequency distribution of summer storm (rainfall) events in terms of depth, duration and inter-storm interval is shown to constitute series of similar exponential distribution. Also, significant correlation is shown to exist between storm depth and duration; but the correlation between storm depth and inter-storm interval or between duration and inter-storm interval appears not to be significant. The factors of depth, duration and inter-storm interval, relating to the statistical properties of summer storm events are prerequisites for the development of any stochastic rainfall model for generating synthetic data.

INTRODUCTION

The Water Quantity Management Branch, Ontario Ministry of the Environment, contributes to the International Hydrological Decade (IHD) programs in the form of detailed hydrologic investigations in several representative study areas in Southern Ontario. Measurement of precipitation is one of the many data collection activities currently being carried out in the Venison Creek drainage basin.

One of the most important and necessary prerequisites to many hydrological studies is the determination of reliable estimates of the areal distribution of precipitation amounts and of the intensity and duration of each storm event for specific time periods. In order to achieve adequate representation in the study area, the precipitation gauge network is often evaluated and modified to provide for the measurement of precipitation events and accumulation within a range of desired accuracy and confidence.

In hydrologic modelling, synthetic rainfall data are usually a requirement as supplementary data input to general watershed models. The development of a stochastic rainfall model requires the definition of the statistical properties of a series of rainfall events. Historical data of storm events provide for the definition of the required probability distribution through freqnency analysis. Such a

analysis. Such a stochastic rainfall model can provide for the generation of the synthetic rainfall data.

Precipitation - Literature Review

Measurement Errors

Errors in precipitation measurements may be grouped generally as instrument errors and sampling errors.

Instrument errors, often referred to as gauge catch-deficiencies, have been attributed to the height of exposure of the gauge relative to ground level, to the size of the gauge orifice and to the effect of air turbulence over the gauge orifice (2, 8, 32)*. For example, it was observed (32) that a gauge with an orifice exposure at or a few inches below ground level, resulted in a lesser catch-deficiency than a similar gauge exposed at one foot above ground level. Continuing investigations by cited researchers are attempting to resolve inconclusive results on the determination of degrees of catch-deficiency for most types of precipitation gauges.

Sampling errors are usually examined for significance and attempts are made to minimize these errors on the basis of one or both of two attributes:
(a) setting and exposure of a gauge at a site so as to minimize the catch-deficiency due to air turbulence (2, 8, 32) and (b) use of a gauge network consisting of a sufficiently large number of gauges so as to measure precipitation events

* Appended Selected Bibliography.

representative of a number of limited small areas. By averaging these measurements, a better estimate of the average for the whole area samples may be determined (1, 6, 8, 11, 12, 16, 28, 29). Minimization of sampling errors, thus has been shown to require that the study area be sub-divided according to those factors that influence local precipitation events (14, 19, 35). The irregularity in areal distribution and variability of precipitation events have been shown to be caused by such factors as orography (5, 16, 17, 22, 33,34), the nature of the precipitation processes and the length of the accumulation period (8, 20, 24).

Areal Estimates

Weighted, areal average precipitation amounts may be determined from the data collected with the use of various computational procedures such as those of the Thiessen-polygon and the isohyetal techniques. The accuracies of these estimates are difficult to determine empirically. However, theoretical treatments (4, 16) of these techniques have attempted to determine optimized estimates of the areal averages and by inference, have asserted their reliability.

Analysis of precipitation data based on the statistical sampling theory of the normal distribution has been used implicitly in computing areal estimates. This method provides

for a statement of accuracy and confidence on the averages, providing also a basis for estimating probable sample sizes with a degree of precision and confidence (6, 8, 11, 19, 21, 29, 35, 37). The application of this theory to this type of data analysis, however, requires the acceptance of the assumptions of independent point measurements, normality and randomness of the samples.

Investigations by Linsley and Kohler, 1951 (21), Hershfield, 1961 (12), Nicks, 1965 (29), have concluded that an increase in the density of a gauge network above a certain minimum does not decrease significantly the standard error of averages and that a dense network may not be necessary for most hydrologic studies, if an occasional large error in an estimate is acceptable.

Systematic sampling errors are inherent in most precipitation gauge networks. Attempts have been made to account for these systematic errors, through analyses based on a stratified random sample (19, 35) and on a reduction of the standard errors for persistence in the data sequence (11, 37).

The association of precipitation measurements recorded at different locations within a specific study area or region has been examined in terms of statistical correlation among gauges (3, 13, 23, 27). These correlation assessments often supplement an overall evaluation of a gauge network.

Hersfield, 1965 (13), used correlation among gauges in a network as a base for developing a relationship for distance between gauges, selected rainfall depths and periods. A further relationship between the inter-station correlation coefficient and the distance between stations was used (27) to determine critical station-distance relationships for use in extension of rainfall records through linear regressions. Also, a similar multiple regression technique was used (23) as a base for the estimation of basin precipitation from the record of a number of selected regional index stations in parts of Southern Ontario.

Storm Frequency Analysis

Recent advances in hydrologic modelling stimulated the development of stochastic rainfall models for use in generating synthetic rainfall data. The applicability of these models to provide synthetic data inputs to general watershed models depends on the ability of the model to simulate short-time rainfall event sequences which possess similar statistical properties to those of the historical data. Preservation of the statistical properties is based on an adequate determination of the frequency or probability distributions of the parameters that characterize the storm events in time.

The frequency distributions of rainfall depths, durations and the intervals between storms form the basis for stochastic models developed (30, 31) for use in synthetizing hourly rainfall data. A further development by Frantz, 1971 (10), considered a multi-station rainfall model for generating hourly rainfall data for a network.

INVESTIGATION

In this report, the compiled precipitation data are evaluated for the reliability and confidence that may be placed in these measurements. Evaluations are assessed through statistical inference based on the significance and reliability of the standard errors and the degree of areal association among the different gauge measurements.

Further evaluation of the frequency distribution of the storm events provide additional knowledge on the basin precipitation regime and prerequisite statistical information for the likely development of synthetic rainfall models.

Objectives

The objectives of this study are summarized as follows:

1. to determine the statistical sampling error of the precipitation measurements in the study area,
2. to determine the degree of statistical, areal association of precipitation measurements among the gauges, by a measure of their inter-station correlation,
3. to evaluate the applicability of the data for use in projecting the density of the gauge network to within specified limitations of accuracy,
4. to evaluate the adequacy of the gauge network for obtaining reliable estimates of the basin precipitation

events which are presumed representative of the general climatic region,

5. to analyse the summer storm events as to their characteristic frequency distribution of intensity, duration, amount or interval between storms.

Study Area

The Venison Creek drainage basin is located in Southern Ontario, situated between latitude 42° 36' N and 42° 49' N and between longitude 80° 30' W and 80° 44' W. The drainage basin is approximately 35 square miles in area, having a rolling topography with elevations ranging from approximately 600 to 780 feet above mean sea level (see Figure 1, Appendix I). The study area is situated within a general climatic region which appears to have on the average, an annual precipitation of 35 inches with approximately 15 per cent of this occurring as snowfall. The major tributaries are perennial. Mean daily flows at the basin outlet range from 10 cfs to 200 cfs. Land use consists predominantly of short-term tobacco crops which depend, to a large extent, on supplementary irrigation during the growing season. Water-takings from creeks and wells form the major sources for these supplies.

Data Collection

The precipitation network in the Venison Creek basin consists of five standard rain gauges and one recording

precipitation gauge. These standard rain gauges of 3.6-inch orifice-diameter, exposed at one foot above ground level, were installed at selected sites in 1966, when the study was initiated. Complete instrumentation, inspection and data-quality control were carried out with the assistance of the Atmospheric Environment Service of Canada. Figure 1 of Appendix I shows the locations of gauges in the drainage basin. Table 1 of Appendix I shows a listing of the stations in terms of location, elevation and position (distance and direction) of the stations relative to one another. Table 2 of Appendix I shows a similar listing of selected regional index stations with locations relative to the study area.

The required data for each gauge were abstracted and summarized from precipitation or climatological station reports compiled in the River Basin Research Section data source files and from published climatological records of the Atmospheric Environment Service of Canada.

Filling Data Voids

There were occasional periods of missing data in the climatological reports. These data voids for any given time and for any given station were supplemented with the use of the following equation for ratio-estimates (36):

$$Y_j = \sum_{m=1}^{(N-1)} w_m \, (\overline{Y}/\overline{X}_m) \, X_{m,j} \qquad \ldots (1)$$

where:

y_j - the required precipitation estimate for a given station for a j^{th} missing data period,

$\overline{Y}$ - the average precipitation at the given station for the periods of complete record,

$x_{m,j}$ - the measured precipitation at the m^{th} station for the j^{th} missing data period,

$\overline{X}_m$ - the average precipitation at the m^{th} station for the periods of complete record,

w_m - the weight given to each of the remaining stations ($m = 1, 2 \ldots, N-1$), subject to the constraint.

$$\sum_{m=1}^{(N-1)} w_m = 1 \qquad \ldots(1a)$$

where:

N - the number of stations in the precipitation gauge network.

In the application of Equation (1), equal station weights were used for simplicity.

Data Summaries

Precipitation records in the Venison Creek basin for 1968, 1969, 1970 and 1971 are shown in tables 3a, 3b, 3c and 3d of Appendix I, as monthly summaries of daily precipitation totals (rain and/or snow) for each gauge.

The number of days for which precipitation was recorded at each site is shown in parentheses next to each monthly total. Ruler-measured snowfall depths from each site were included into the respective monthly total precipitation (assuming 10 inches depth of snowfall equivalent to one inch of rain).

Table 4 of Appendix I shows a summary of selected daily average precipitation of amounts $\geq$ 0.38 inch. A precipitation value of 0.38 inch was selected for use as it was felt that this amount represented the minimum storm rainfall which would contribute to a significant increase in basin runoff.

Recorded hourly precipitation data from the main station, Langton X_1, are summarized in tables 5a to 5d and tables 6a and 6d of Appendix I as absolute frequencies of storm events, based on the storm durations and intensities, respectively. The data were abstracted from compiled monthly summaries of recording, precipitation station reports.

Table 7 of Appendix I shows monthly summaries of daily precipitation totals, for three years, for two groups of selected regional index stations. These were used as supplementary data in further analyses of the network.

NETWORK EVALUATION

Several types of analyses were performed on the compiled precipitation data for use in the evaluation of the gauge network. These analyses include the determination of sampling errors, inter-station correlation and the theoretical projection of the gauge network for desired accuracies at different confidence levels. The comparison of averages of precipitation measurements in the basin with those of the general climatic region served as a supplement to the evaluation.

Statistical Analysis - Sampling Theory

The density of the standard rain gauges was the basis for the following analyses and evaluations. Instrument, observational and gauge exposure errors were assumed to be negligible.

Statistical sampling theory of normal distribution was the method chosen for analysing the precipitation data. The data were taken to be comprised of random samples with a normal distribution; that is, it was assumed that each rain gauge gave independent point estimates of the precipitation amount in the basin, for each storm period and that each gauge carried equal weight as a data point in the analysis.

The statistical parameters, average and variance, were used as measures for assessing the adequacy of the gauge network density in terms of how much confidence could be placed in the data collected.

By accepting the inherent assumptions for the application of the sampling theory, the precipitation data for a given accumulation period may be analysed with the use of standard statistical equations (9, 36, 38) specified as follows:

$$\bar{X}_j = \frac{1}{N} \sum_{m=1}^{N} X_{j,m} \qquad \ldots(2)$$

$$S_j = \left[\frac{1}{N-1} \sum_{m=1}^{N} (X_{j,m} - \bar{X}_j)^2\right]^{\frac{1}{2}} \qquad \ldots(3)$$

$$S_{\bar{X}j} = S_j / N^{\frac{1}{2}} \qquad \ldots(4)$$

$$E_{aj} = t_\alpha \, S_{\bar{X}_j} \qquad \ldots(5a)$$

where:

$\bar{X}_j$ - sample average of the basin precipitation for a j^{th} accumulation period,

$X_{j,m}$ - the m^{th} point observation for a j^{th} accumulation period,

S_j - the standard deviation of the point measurements for the j^{th} accumulation period,

$S_{\overline{X}j}$ - the standard error of the average precipitation measurements for the j^{th} accumulation period,

E_{aj} - the absolute standard error (and/or confidence limit) of the average for the j^{th} accumulation period,

t_{α} - the standard normal deviate at a selected significance probability level, α, which sets the confidence limit; $m=1,2,3,\ldots\ldots N$ number of point (gauge) observations, and

j - selected accumulation period (day, month or year).

From the sample of N observations, the relative standard error may be expressed approximately as:

$$E_{rj} = E_{aj}/\overline{X} \qquad \ldots(5b)$$

where E_{rj} is the relative standard error (and/or degree of accuracy) for the j^{th} accumulation period. Because of the inherent large variation in sampling errors for any selected accumulation period, it seems reasonable to state a range for a desirable degree of accuracy and confidence. For this analysis, an areal average precipitation estimate that satisfies the precision and confidence given by expression (6), would be regarded for practical purposes, as a satisfactory estimate for use as reliable input to a general water-balance analysis;

$$E_{rj} \leq 0.10, \text{ for } \alpha \leq 0.32 \qquad \ldots(6)$$

For any given period, an average precipitation $\overline{X}$, with a confidence limit, c.l. = $\pm t_{\alpha} S_{\overline{X}}$, can be checked for acceptability against a standard statistical table of student's t-values (9, 36) for $\alpha \leq 32\%$ and (N-2) degrees of freedom. For large samples, a c.l. = $\pm 1.0\ S_{\overline{X}}$ corresponds to a 68% confidence level (i.e. $\alpha = 0.32$) and a c.l. = $\pm 2.0\ S_{\overline{X}}$ corresponds to a 95% confidence level (i.e. $\alpha = 0.05$).

Estimates and Variations

An available computer program (18), based on equations (2) and (3), was utilized to perform the basic computations. Auxiliary computations based on equations (4) and (5) were desk-calculated. The results of the program application are summarized in tables 8a to 8e and 9 of Appendix II. Shown are the average monthly precipitation (the arithmetic and Thiessen-polygon weighted averages are given for the purpose of comparison), standard deviation and the relative standard error of average for each month. As an example, the results based on 1968 data indicate that the average precipitation estimates for all months, excluding February, July and December, were determined with an accuracy $E_r \leq 10\%$ for a 1.0 $S_{\overline{X}j}$ c.l. The annual average and the averages for June, August and September were determined with an $E_r \leq 5\%$ for a 1.0 $S_{\overline{X}j}$ c.l. The results for the 1969, 1970 and 1971 data can be examined in the same manner. However, the monthly

averages differ in the magnitude of standard errors within and among years. Although the extent of the sampling variation was nearly the same for each month, it was possible to differentiate between months with consistently poor estimates, (e.g. July) and months with consistently good estimates (e.g. April, May).

The four years of data were grouped for one-sample analysis by year and by month, to determine how accurate the data represent estimates of the long-term monthly averages. This portion of the analysis was based on a four-station network. Table 8e of Appendix II shows the results of the analysis. Average annual precipitation was determined with an accuracy $E_r \leq 10\%$ for a 1.0 $S_{\bar{X}j}$ c.l. For the same degree of confidence, however, monthly estimates produced accuracies, $E_r \geq 15\%$; indicating that the four-year data averages are poor estimators of the long-term averages.

An attempt was made to investigate the presumption that the accuracy of the areal estimates improves with an increase in the amount of precipitation and with an increase in the length of the accumulation period. Data for a shorter accumulation period (daily) and for different amounts of precipitation were compiled for analysis. Table 4 of Appendix I shows the raw data for selected average daily precipitation, arranged sequentially into three groups: 0.38 inch $\leq \bar{X} <$ 1.0 inch,

1.0 inch $\leq \bar{X} < 2.0$ inches and $\bar{X} \geq 2.0$ in. A similar analysis, as outlined for the monthly and yearly data, was performed on each group of data; the results are summarized in Table 9 of Appendix II, which indicate that for the selected group, $\bar{X}$ (daily) $\geq$ 2.0 inches, the relative standard errors were of comparable magnitude with those errors for the corresponding monthly estimates. However, for the other two groups with $\bar{X}$ (daily) <2.0 inches but $\geq$ 1.0 inch and $\bar{X}$ (daily) <1.0 inch but $\geq$ 0.38 inch, the errors were, in most cases, greater and less comparable with those of the corresponding monthly averages. Therefore, it may be construed that for daily precipitation of large amounts, the areal distribution of the precipitation event(s) is sufficiently uniform to result in smaller standard errors of the average, than for daily precipitation events with smaller amounts.

Inter-Station Correlation

Further evaluation of the extent of the degree of uniformity in the areal distribution of precipitation events was assessed by an inter-station correlation analysis. High correlations among the different gauge measurements, for a given period, would indicate reasonably uniform areal distribution of precipitation within the study area. Inter-station correlation would also be valuable in

the improvement of the gauge network density relative to the attainment of a certain degree of accuracy in interpolated precipitation estimates at other intermediate locations within the study area.

Inter-station correlation between pairs of gauges is based on the standard correlation equation (7, 18, 36, 38):

$$r_{k,m} = \frac{\sum_{i=1}^{N} ((X_{k,i}-\overline{X}_k)(X_{m,i}-\overline{X}_m))}{(N-1)\ S_m\ S_k} \qquad \ldots(7)$$

where:

$r_{k,m}$ - the correlation coefficient between gauges k and m,

$X_{k,i}$ and

$\overline{X}_k$ - the i^{th} point observation and the average precipitation, respectively, at station k,

$X_{m,i}$ and

$\overline{X}_m$ - the i^{th} point observation and the average precipitation, respectively, at station m,

S_k and

S_m - the standard deviations of the point observations at stations k and m, respectively,

$i = 1, 2, 3, \ldots, N$ - observations,

k and m are used to designate selected stations.

Table 1 of Appendix I summarizes the position matrix of the gauge network which was used as an aid in the rational interpretation of the inter-station correlations.

The computations based on Equation (7) were performed on the raw data of tables 3a to 3d of Appendix I, using available computer programs (18). The results are summarized in tables 10a and 10b of Appendix II.

The correlation matrix, based on monthly precipitation (1968-71), is shown in Table 10a. It is seen that the correlation coefficients are consistently high for all months, with the value of $r \geq 0.8$ in the majority of cases. A station (gauge) correlated with itself gives a value of 1.0, by definition. Table 10b shows the correlation matrix for the gauges for annual precipitation. The high degree of areal association among gauge measurements is re-emphasized, which indicates that precipitation events were reasonably uniformly distributed within the basin. This conclusion can be used to support arguments on the reliability of the areal precipitation estimates for the basin determined for specified accumulation periods.

Inter-station relationship was further examined through a multiple regression procedure (7, 18, 36, 38). The result was used as a basis for investigating the strength of relationship among the gauges when considered simultaneously. The generalized relationship which was used in the computations may be expressed as:

$$X_k = a_k + \sum_{m}^{n} b_m X_m \qquad \ldots(8)$$

where:

X_k - the selected dependent variable (station),

X_m - the selected independent variable,

a_k - the corresponding regression constant,

b_m - the partial regression coefficient,

$m = 2,\ldots n$ - independent variables (remaining stations in the network).

A stepwise multiple regression routine (18) was used to determine the order in which the independent variables account for variation in the dependent variable. Each station in turn, was designed as a dependent variable, relative to the other stations as independent variables.

Tables 11a, 11b and 11c of Appendix II show the results of the analysis for the network stations. The analysis was based on monthly precipitation amounts for three different periods: summer months (June-September, inclusive), winter months (December-March, inclusive) and the months April, May, October and November, termed pre-seasons. It was assumed that precipitation events during these time periods were samples from the same populations. The results of the analysis indicated that simplified regressions with the main station Langton X_1, as the independent station, may

be used for estimating missing data at any one of the secondary stations. These simplified regressions appeared to be reasonable and sufficient relationships for predictions or for filling data voids seeing that the inclusion of another station in each regression resulted in some, but not significant improvements (larger proportion of variance R^2 explained, and a reduction in the standard error of estimate).

Gauge Network Projection

It is often necessary to assess the number of gauges required to measure consistent estimates of the basin areal precipitation with a given degree of accuracy and confidence. Equations (5a) and (5b) provide the basic relationships for projecting a gauge network with specified accuracy and confidence. The relationship for determining the projected number of gauges, N' , for a desired degree of accuracy β_r, at a given significance level, α, may be expressed as:

$$N' = (t\alpha)^2 \frac{(S/\overline{X})^2}{\beta_r^2} \qquad \ldots(9)$$

where $\overline{X}$ and S are the average and standard deviation of any given sample. With the availability of replicate sample estimates of $\overline{X}$ and S, a procedure is used for minimizing an estimated sampling error for a given average precipitation. This was based on the assumption that there exists a unique relationship between standard error, E_a and average precipitation, $\overline{X}$, expressed generally by:

$$E_a = f\ (\bar{X}) \qquad \ldots(10a).$$

Consequently, a least-square regression was attempted to fit the following relationship to the data:

$$E_r = C\ (\bar{X})^b \qquad \ldots(10b)$$

where E_r is the relative standard error. C and b are a constant and coefficient, respectively.

If there exists a statistically significant relationship between sample estimates of E_r and $\bar{X}$, equations (9) and (10b) can be used to develop a generalized graphical relationship for a projected gauge network relative to average depth of precipitation for a given degree of accuracy and confidence. For ease of computation, both sides of Equation (9) were divided by the original network size, N, and re-arranged to give:

$$K = E_r^{\ 2} / \beta_r^{\ 2} \qquad \ldots(11)$$

where $K = N'/_N$ is the ratio of the projected sample size to the original sample size. Regressed estimates of E_r for given $\bar{X}$ can be determined from an empirically derived Equation (10b) and K can be computed by Equation (11) for a desired degree of accuracy, β_r, at a specified significance level.

The significance of the inter-station correlations computed for the network limits the validity of the assumption of independent rain gauge observations. An attempt to remove

the limitations on this assumption was made by employing an analytical procedure for reducing the standard errors. The method for reducing standard errors, described by Sutcliffe, 1966 (37), Herbst and Shaw, 1969 (11), was employed. The reduced standard errors, RE_r, were computed with the use of the relationship:

$$RE_r = \sqrt{1 - r^*}\, E_r \qquad \ldots (12)$$

where r* is the correlation coefficient between concurrent sequences of data for two independent periods; $\sqrt{1 - r^*}$ is referred to as the "persistence factor" (37). Table 12 of Appendix II shows a listing, by month, of the correlation coefficients between data years. The correlation coefficients, r* (68/69) and r* (70/71), were used in the reduction of the standard errors for 1968 and 1971 estimates, respectively. The averages of r* (68/69) and r* (69/70) were used to reduce 1969 standard error estimates and the averages of r* (69/70) and r* (70/71) were used to reduce 1970 standard error estimates.

Three different data groups were selected arbitrarily for further analysis: $\overline{X}$ (monthly) $\geq$ 0.01 inch, $\overline{X}$ (daily) $\geq$ 1.0 inch and 0.38 inch $\leq \overline{X}$ (daily) < 1.0 inch, where $\overline{X}$ (monthly) and $\overline{X}$ (daily) are the averages of the monthly and daily totals for the network gauges, respectively. Table 13

of Appendix II shows the results of the regression analysis based on the linearized form of Equation (10b). Summarized are the empirical equations and the corresponding significant statistical parameters. These empirical equations, together with Equation (9), were used to develop general graphical relationships between desired accuracy and average precipitation for various network densities. Figure 2 of Appendix II shows the confidence-reliability curves for average monthly precipitation with various densities of the gauge network. It may be observed that the network of four gauges is sufficient to determine $\bar{X}$ (monthly) $\geq$ 0.5 inch with an accuracy of $\leq$ 15% at the 68% confidence level; however, for the same accuracy, but at 95% confidence level, a network in the order of 36 gauges would be required to determine $\bar{X}$ (monthly) $\geq$ 1.0 inch. Figure 3 of Appendix II shows a similar relationship, based on the reduced standard error. It is seen that there is a substantial improvement in the measure of the accuracy of the estimates for a given network. For example, for $\bar{X}$ (monthly) $\geq$ 0.5 inch, the network of four gauges is sufficient for determining these estimates with an accuracy of $\leq$ 7% at the 68% confidence level; and for $\bar{X}$ (monthly) $\geq$ 1.0 inch, with an accuracy of $\leq$ 15% at the 95% confidence level.

Figure 4 of Appendix II shows the graphical relationship between precipitation averages and degrees of accuracy for the three different data groups. A comparison of curves (2) and (3) indicates that the rate of increase in degree of accuracy with an increase in precipitation amounts is greater for $\bar{X}$ (daily) > 1.0 inch than for 0.38 inch $\leq$ $\bar{X}$ (daily) < 1.0 inch. However, a comparison of curves (1) and (2) or (1) and (3), indicates that a larger amount of precipitation for a given period is more effective for arriving at smaller standard error of average than is a lengthening of the accumulation period.

In general, it may be inferred that the accuracy of the areal precipitation averages increases with an increase in the number of gauges and with an increase in the depth of the precipitation for given accumulation periods.

Basin Versus Regional Estimates

The gauge network was examined further, through a relationship between records of precipitation in the study area and records at selected long-term index stations outside the study area, within the same general climatic region. It was presumed that these stations were representative index stations for the Lake Erie and Niagara counties and west-central counties of Southern Ontario. Table 2 of

Appendix I summarizes the station positions, relative to the main station Langton, X_1. Group 1 consists of three stations located within a radius of 11.0 miles and group 2 consists of five stations located with an annulus of radius of 19 to 40 miles from the main station X_1. The basin average monthly precipitation, $\bar{X}_B$, and monthly precipitation at station X_1 were compared on the basis of (a) a three-year average monthly precipitation differences between the basin average, $\bar{X}_B$, and the regional average, $\bar{X}_R$, (b) the difference between the three-year average point precipitation at station X_1 and the long-term average precipitation at each of the group 1 stations, and (c) the degree of inter-station correlation between $\bar{X}_B$, X_1 and group 1 and group 2 stations, respectively.

Difference Between Averages

The statistics used for the test of significance for differences between averages of two groups of observations, assumed from the same population (9, 36), were based on the student's t-test:

$$t^* = (\bar{X}_1 - \bar{X}_2) \; / \; (S_1^2 + S_2^2)^{\frac{1}{2}} \ldots (13)$$

where:

t^* - standard deviate,

$\bar{X}_1$ and

S_1^2 - the basin (or main station) precipitation average, and variance, respectively,

$\overline{X}_2$ and

S_2^2 - selected long-term station precipitation average and variance, respectively.

A significant difference between averages is subject to the probability condition that $t^*_\alpha \geq t_\alpha$; where t_α is the value of the standard deviate, determined from tables (9, 36) at the significance level, α, for $(n_1 + n_2 - 2)$ degrees of freedom, where n_1 and n_2 are the number of observations at the main station and the regional station, respectively.

The statistical parameters used in the tests for significant differences between basin average, $\overline{X}_B$, and regional average, $\overline{X}_R$, are summarized in Table 14 of Appendix II. It is seen that the differences between $\overline{X}_B$ and $\overline{X}_R$, are not statistically significant at the 5% significance level ($t_{0.05,4} = 2.78$), except for the November and the annual estimates. Therefore, it may be concluded generally, that values of areal average monthly precipitation for the basin are reasonably representative sample estimates of precipitation for the region considered.

The individual station average for the region appears to be highly variable as indicated by the coefficient of variation, $S/\overline{X}$, (Table 15 of Appendix II) when computed for the long-term averages of the group 1 stations. Table 15 of

Appendix II summarizes the parameters for the test of statistical significance for the difference between the three-year average at the main station X_1 and the long-term average at each of the group 1 regional stations. It is seen that these differences for both the monthly and annual averages are not statistically significant at the 95% confidence level, except for isolated months. It may be construed that the time variability of the point precipitation at the long-term stations reflects the probable nature of the long-term variability of point precipitation within the study area.

Statistical Association

The significant statistics for the areal associations between the basin precipitation ($\overline{X}_B$ or X_1) and the selected regional stations' precipitation are summarized in Table 16 of Appendix II. The correlation matrix shows that $\overline{X}_B$ and X_1 are highly correlated with group 1 stations and similarly, but less so, with group 2 stations. There are also significant correlations among the regional stations themselves. The reduction in correlation between $\overline{X}_B$ or X_1 and the most distant stations supported the presumption that inter-station correlation decreases with an increase in distance from the 'pivot' station.

A stepwise multiple regression was performed in turn on X_1 and $\overline{X}_B$ as dependent variables, and the group 1 stations as independent variables; a similar type of analysis was performed with three of group 2 stations (those with the highest correlation with X_1 or $\overline{X}_B$). The results are summarized in Table 17 of Appendix II. It is seen that all the regressions are significant, with the expressed multiple correlation coefficient of value $R \geq 0.9$ in each case. The regressions, with group 1 stations as independent variables, show that each of the index stations is a significant variable, with Tillsonburg emerging as the principal station, accounting for 81.5% and 83.4% of the variance, respectively, in the case of the regression for X_1 and $\overline{X}_B$. The small negative values for the intercept in either regression indicated that these constants are negligible. Hence short-term basin precipitation amounts can be supplemented by a linear regression, through the origin, using recorded precipitation events at the selected group 1 stations as the operating sample. The regression for the group 2 stations followed a similar conclusion, with Port Dover as the principal independent station; however, the regression constants are not marginal and the estimation of basin precipitation from these group 2 stations by a linear regression through the origin would be less applicable.

STORM CHARACTERISTICS

Selected rainfall events in the basin were analysed for characteristic statistical properties through the frequency analysis of the series of storm (rainfall) events. The extent and the degree of statistical association among the storm characteristic parameters were also examined.

Storm Frequency Analysis

The precipitation records at the main station, Langton X_1, were shown to be a suitable index of the basin precipitation; therefore, the recording precipitation gauge data at this station were examined for the frequency distributions of storm intensities, durations, amounts and interval between storms.

Tables 5a to 5c and 6a to 6c of Appendix I, summarize the storm data in terms of frequency of storm, total amounts and intensities. The series of summer storm events for the period June to September were selected, as an example, for the frequency analysis. The data were also analysed for time-variability of large storms and for evidence of a type of frequency distribution for each of the storm event series.

A storm was crudely defined as a continuous rainfall event of hourly measurements in amount $\geq$ 0.01 inch. The compiled data for the period (four years, each of four summer months), provided 256 storms with duration of 1 to 15 hours, total amount of 0.01 to 3.56 inches and intensity of 0.01 to

0.95 in./hr. Table 18a of Appendix II, shows the relative frequency of storm duration, according to selected class-intervals, for the series of storm events from the four consecutive summer periods (1968 to 1971). The relative frequency of all the combined storms by month, has a range of 0.281 to 0.223 for the months of June and August, respectively, with approximately equal relative frequency for the months of July and September. This indicates that the number of storm events were nearly uniformly distributed throughout the summer months; however, the relative frequency for storm duration has a range of 0.535 for the one-hour duration, to 0.004 for the 12 to 18-hour duration. Therefore, the durations of the storm events during the summer months were highly variable, exhibiting a non-uniform frequency distribution. The frequency of the inter-storm interval, (Table 18b of Appendix II) exhibited also a high degree of non-uniformity. That is, the magnitudes of the relative frequency range from 0.432 to 0.008 for the one to six-hour and the >288-hour inter-storm interval. Table 18c of Appendix II summarizes a similar type of frequency distribution for the grouped storm intensities. It is seen that an intensity of 0.01 to 0.09 in./hr. experienced a relative frequency of 0.766, as compared to 0.025 for an intensity of 0.50 to 0.99 in./hr.; an hourly intensity of $\geq$ 1.0 in./hr. had negligible

occurrence. The month of June has approximately equal chance for a number of storm events, but occurrences of storms with long duration are most probable. For example, 31% of all recorded summer storm-hours occurred in June as compared to 16.4% for the month of August.

It was assumed that each of the series of storm duration, inter-storm interval and storm total amount, was an independent random series. With this assumption and by neglecting possible serial correlation within any given storm sequence, an attempt was made to examine each series of data for a type of frequency distribution, by graphical fitting. The frequency distribution plots for the sequences of storm amounts, storm duration and inter-storm interval as shown in figures 5, 6 and 7 of Appendix II, depict similar types of exponential decay curves. This indicates that summer storm events are mere permutations from populations with similar probability distributions. The probability density function curves (of figures 5, 6 and 7 of Appendix II) were fitted with a theoretical exponential density function relationship ($f(x) = \lambda e^{-\lambda x}$, where $f(x)$ is the probability density function and x a variable with mean $1/\lambda$), assumed to be characteristic of the population.

Figure 8 of Appendix II shows the log-normal probability plots for storm amounts of given durations. The linear

curves, fitted visually, appear to support the presumption of log-normally distributed series. The duration classes, four to six hours and six to nine hours, were used merely for the convenience of a larger sample size. The curves demonstrate the probability that a storm of given duration will exceed or not exceed a specified amount. Similarly, Figure 9 of Appendix II, shows the probability curves (developed from Figure 8 of Appendix II) of storm durations for given storm amounts. These curves also demonstrate the probability that a storm of given amount will exceed or not exceed a specified duration.

The results of the frequency analysis indicate that an exponential distribution of the type described for the storm event series would be a reasonable definition of the probability distribution required for the development of a stochastic model for simulating rainfall data.

Storm Parameters Relationship

Table 18d of Appendix II shows another frequency distribution of the grouped summer storms by duration, according to arbitrarily selected class intervals: trace storms, 0.01 to 0.09 inch, moderate storms, 0.10 to 0.39 inch and large storms, $\geq$ 0.4 inch. Table 19 of Appendix II lists a selected group of storms with amount $\geq$0.40 inch and/or

duration $\geq$ three hours, showing as an example, the extent of the time variability of the hourly storm intensity within and among storms. It may be observed that there is no consistency, for example, between storm duration and the maximum one-hour intensity. Table 20 of Appendix II lists the correlation coefficients for the relationship between storm amount and duration, between storm amount and inter-storm interval and between inter-storm interval and duration, respectively, for each data year and for each storm group. It is seen that for the data-year sequences, there were greater degrees of correlation between storm amounts and duration than between storm amounts and inter-storm interval or between storm duration and inter-storm interval. The high degree of statistical association between storm amount and duration was asserted by the larger correlation coefficients for the better defined storm class (large storms) or storm group ($X \geq 0.40$ inch and $T \geq$ three hours). Therefore, these relationships suggest, that for a properly defined storm sequence, the association between storm depth and duration is an additional significant statistic to be considered in formulating a model for use in generating synthetic rainfall data.

CONCLUSIONS

The statistical analyses of precipitation data in the Venison Creek drainage basin provide for a first approximate evaluation of the precipitation gauge network, with the following conclusions:

1) The precipitation gauge network of four stations appears to be adequate for measuring the basin average monthly precipitation of amounts $\geq$ 0.5 inch with a relative standard error of $\leq$ 15%, at the one standard error confidence limit. In general, the accuracy of the areal averages increases with an increase in the amount of precipitation for a given period and with an increase, but less so, in the length of the accumulation period; that is, greater accuracies are achieved for estimates based on annual accumulations rather than for the monthly and/or daily accumulations.

2) A high degree of inter-station correlation is evident among the gauge measurements for the monthly and annual total precipitation. Simple regression equations using the main station Langton X_1, as an independent variable, and the secondary stations as dependent variables, in turn, proved to have significant relationships for use in filling data voids or supplementing monthly precipitation amounts in the basin.

3) Empirical relationships for the regressions between standard errors and the averages were derived to supplement the theoretical relationship used in extending the size of the existing gauge network, which is presumed capable of measuring areal precipitation amounts within specified accuracy limitations. A similar analysis, based on reduced standard errors, resulted in a significant reduction in size of the gauge network for the same limitations on accuracy. A greater confidence and increased accuracy in the precipitation measurements for use as input to monthly water balance studies, may be achieved by an increase in the number of gauges to the order of twice the size of the existing network. Further measures of accuracy can be determined with an analysis for reduced standard errors. If it is necessary to utilize daily (or hourly) inputs for more detailed hydrologic models, the increase in the size of the network would be optimized with the use of automatic recording-type precipitation gauges; thereby better representing the areal distribution of the precipitation events and basin-average precipitation. In this regard, knowledge of the errors and confidence limits that are associated with these small-time averages is of greater importance.

4) The lack of significant differences between average precipitation amounts in the study area and those in the specified climatic region, indicates that the observed precipitation amounts for the study area are representative sample estimates of the precipitation events within the general region. The

regression relationships developed between the basin precipitation and precipitation records of selected regional stations can be used in procedures for supplementing or extrapolating data in the study area.

5) The assessment of the storm rainfall data, through a frequency analysis, indicates that occurrences of summer storm events are nearly uniformly distributed throughout the summer months (June, July, August and September). However, the greatest number of storm hours occur during the month of June and the least during the month of August. An examination of the frequency of storm events, based on amount, duration and inter-storm interval, depicts similar types of exponential cumulative frequency distribution curves. These types of frequency curves imply that the summer storm events are mere permutations from the same exponentially distributed series. Frequency distributions of storm depth for given durations or storm duration for given depths appear to be decidedly log-normally distributed. Examination of all the summer storms with total amount $\geq$ 0.40 inch and/or duration $\geq$ 3 hours, show that there exists a high degree of variability in magnitude of intensity within storms and between storm events. There appears, however, to be appreciable correlation between total depth and duration of storm, but negligible correlation between storm depth and inter-storm interval and between storm duration and inter-storm interval. The likely development of a stochastic rainfall model should consider the storm

events, depth, duration and inter-storm interval as belonging to similar statistical populations with exponential probability distributions. Depth and duration should be considered as dependent series, and inter-storm interval as an independent series from depth and duration.

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APPENDIX I

Data Summaries

APPENDIX I

List of Figures

List of Tables

APPENDIX I

List of Tables

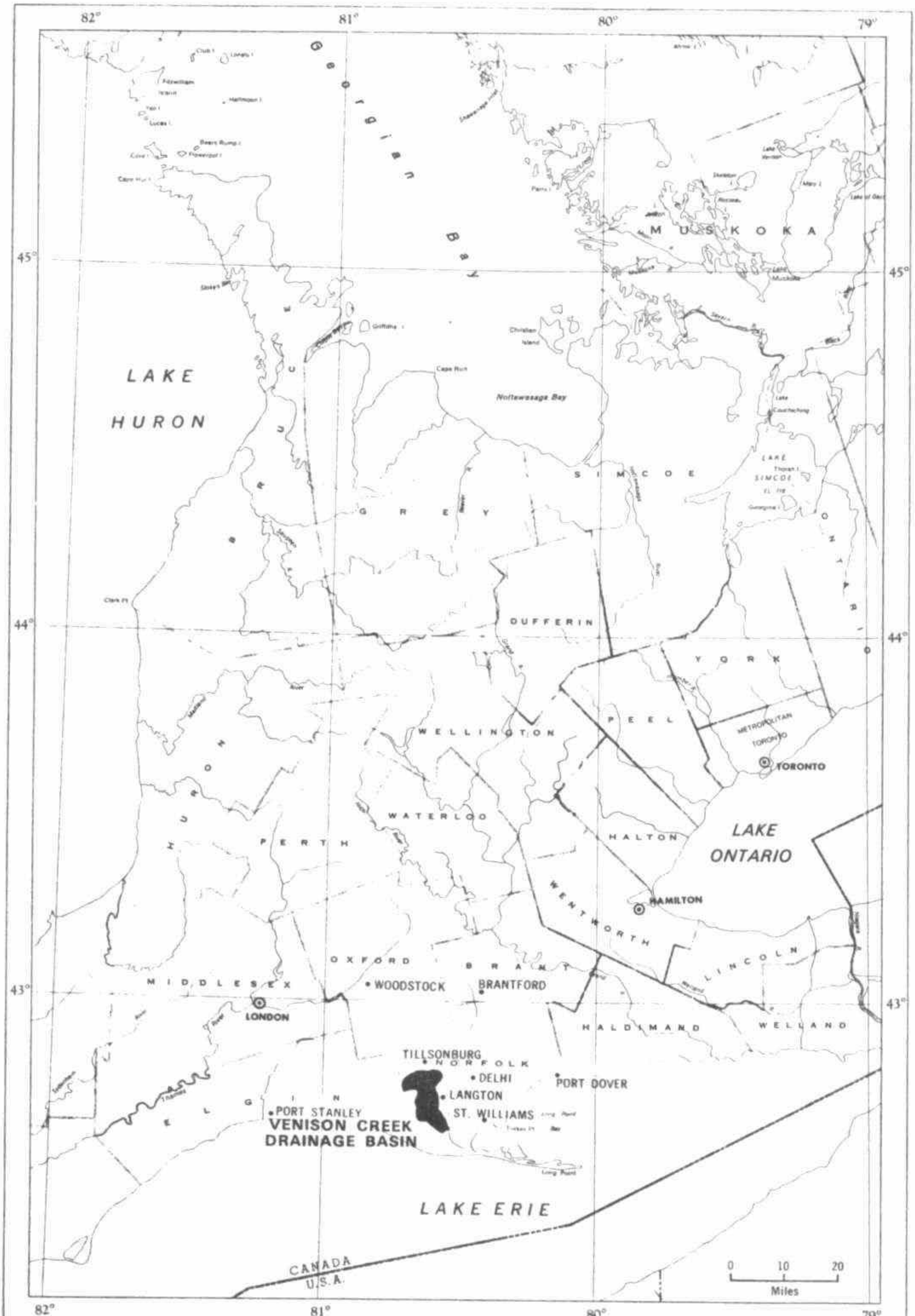

Figure 1a. Location of the Venison Creek drainage basin in Southern Ontario.

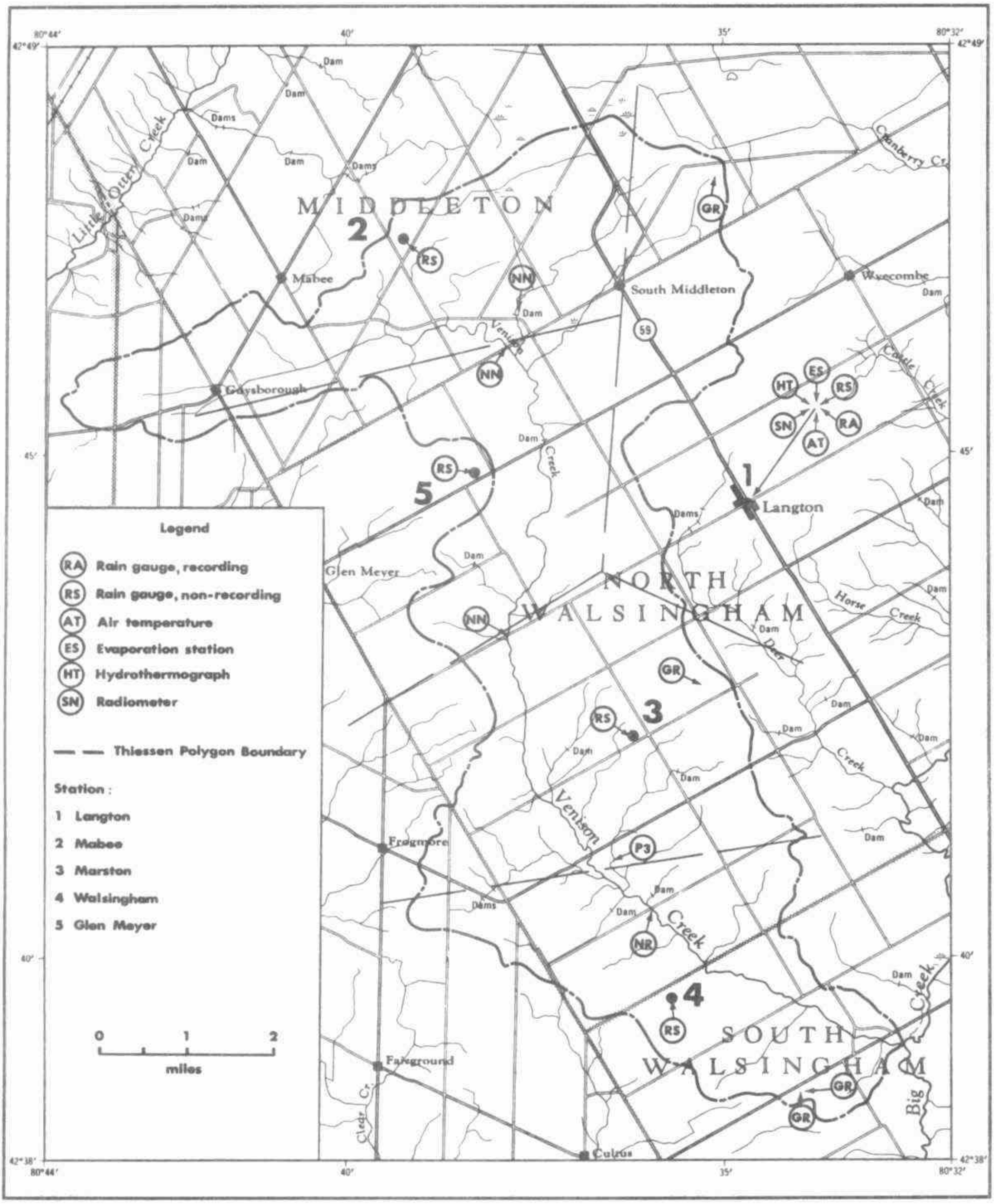

Figure Ib. Venison Creek Drainage Basin and Surrounding Area: Precipitation Gauge Network.

Table 1. Location and Relative Position of Gauges in the Precipitation Gauge Network in Venison Creek Basin

	Location			Distance and Direction									
				X_1		X_2		X_3		X_4		X_5	
Stn.	Lat.-N	Long.-W	Elv.	N(+) S(-) (mi.)	E(+) W(-)	N(+) S(-) (mi.)	E(+) W(-)	N(+) S(-) (mi.)	E(+) W(-)	N(+) S(-) (mi.)	E(+) W(-)	N(+) S(-) (mi.)	E(+) W(-)
X_1	42° 45'	80° 35'	730	0	0								
X_2	42° 46'	80° 41'	775	+1.2	-5.2	0	0						
X_3	42° 42'	80° 36'	710	-3.5	-0.9	-4.6	+4.3	0	0				
X_4	42° 40'	80° 36'	675	-5.8	-0.9	-6.9	+4.3	-2.3	0	0	0		
X_5	42° 45'	80° 38'	755	0	-2.6	-1.2	+2.6	+3.5	-1.7	+5.8	-1.7	0	0

X_1 - Langton

X_2 - Mabee

X_3 - Morston

X_4 - Walsingham

X_5 - Glen Meyer

Elv.- Elevation in feet above mean sea level

N(+), S(-), E(+), W(-) - direction.

Table 2. Location of the Selected Regional Long-Term Precipitation Stations and their Positions Relative to the Location of the Main Station, Langton, in Venison Creek Basin

	Location			Position Relative to Langton, X_1	
	Lat.-N	Long.-W	Elv.	N(+) S(-) (mi.)	E(+) W(-)
Langton, X_1	42° 45'	80° 35'	730	0	0
Tillsonburg, T	42° 51'	80° 43'	760	+6.9	-6.9
St. Williams, S_W	42° 40'	80° 25'	685	-5.8	+8.6
Delhi, D	42° 52'	80° 33'	760	+8.1	+1.7
Port Dover, PD	42° 47'	80° 13'	610	+2.3	+18.9
Brantford, B	43° 09'	80° 14'	671	+27.6	+18.0
Woodstock, W	43° 08'	80° 46'	925	+26.5	-9.5
London-A, L	43° 02'	81° 09'	912	+19.5	-29.4
Port Stanley, PS	42° 40'	81° 13'	600	-5.8	32.6

Elv. - Elevation in feet above mean sea level.

Table 3a. 1968 Data: Monthly Precipitation Summary - Venison Creek Drainage Basin

	Station - Precipitation (inches)														
	Langton			Mabee			Morston			Walsingham			Glen Meyer		
Month (1968)	Rain	Snow	Total	Rain	Snow	Total	Rain	Snow	Total	Rain	Snow	Total	Rain	Snow	Total
Jan.	2.32	1.72	4.04(10)*	1.72	1.41	3.13(8)	2.25	0.60	2.85(5)	3.01	1.38	4.39(8)	1.87	0.77	2.64(9)
Feb.	0.56	0.98	1.54(8)	0.62	0.51	1.13(9)	0.48	0.53	1.01(4)	0.44	0.42	0.86(4)	0.47	0.20	0.67(2)
Mar.	2.03	-	2.03(12)	2.18	-	2.18(9)	1.99	-	1.99(11)	1.73	-	1.73(9)	0.92	0.34	1.26(7)
Apr.	2.17	-	2.17(9)	1.80	-	1.80(9)	2.18	-	2.18(8)	2.57	-	2.57(7)	1.72	-	1.72(9)
May	3.31	-	3.31(13)	2.38	-	2.38(13)	3.08	-	3.08(10)	2.96	-	2.96(13)	2.67	-	2.67(11)
June	6.20	-	6.20(12)	5.85	-	5.85(11)	6.10	-	6.10(10)	5.90	-	5.90(9)	6.17	-	6.17(10)
July	1.24	-	1.24(5)	2.12	-	2.12(7)	0.74	-	0.74(4)	0.68	-	0.68(4)	1.39	-	1.39(4)
Aug.	4.00	-	4.00(14)	3.76e	-	3.76e	3.52	-	3.52(8)	4.14	-	4.14(7)	4.45	-	4.45(7)
Sept.	4.26	-	4.26(12)	3.77		3.77(9)	4.34	-	4.34(8)	4.21	-	4.21(7)			3.75e
Oct.	3.34	-	3.34(13)	3.22	-	3.22(11)	4.15	0.10	4.25(11)	3.05	-	3.05(12)			3.11e
Nov.	3.84	0.61	4.45(13)	3.38	0.30	3.68(13)	4.11	0.62	4.73(13)	4.94	0.40	5.34(12)			3.56e
Dec.	3.31	1.17	4.48(13)	2.56	0.22	2.78(10)	4.91	0.60	5.51(12)	4.07	0.50	4.57(11)			3.92e
Total	36.56	4.48	41.04	33.32	2.44	35.76	37.85	2.45	40.30	37.74	2.70	40.44			35.40

e - estimated

*(10)- no. of precipitation days

Table 3b. 1969 Data: Monthly Precipitation Summary - Venison Creek Drainage Basin

Month (1969)	Station - Precipitation (inches)											
	Langton			Mabee			Morston			Walsingham		
	Rain	Snow	Total	Rain	Snow	Total	Rain	Snow	Total	Rain	Snow	Total
Jan.	3.40	1.03	4.46(15)	4.06	0.55	4.61(10)	3.85	1.50	5.35(11)	4.14	0.80	4.31(11)
Feb.	0.19	0.44	0.63(9)	0.26	0.16	0.42(4)	0.10	0.45	0.55(6)	0.38	0.28	0.66(4)
Mar.	1.48	0.34	1.82(10)	1.23	0.14	1.37(6)	1.30	0.40	1.70(6)	1.52	-	1.52(5)
Apr.	5.24	-	5.24(10)	5.56	-	5.56(10)	4.50	-	4.50(10)	5.35	-	5.35(9)
May	5.32	-	5.32(16)	4.66	-	4.66(13)	5.72	-	5.72(16)	4.70	-	4.70(12)
June	2.83	-	2.83(18)	2.98	-	2.98(16)	2.90	-	2.90(16)	3.13	-	3.13(14)
July	3.89	-	3.89(12)	3.17	-	3.17(13)	4.28	-	4.28(12)	6.34	-	6.34(11)
Aug.	1.61	-	1.61(4)	0.37	-	0.37(3)	0.30	-	0.30(3)	0.85	-	0.85(3)
Sept.	1.28	-	1.28(5)	1.40	-	1.40(5)	1.51	-	1.51(6)	1.42	-	1.42(5)
Oct.	2.61	0.12	2.73(11)	3.07	0.21	3.28(9)	2.70	0.50	3.20(11)	2.02	0.41	2.43(9)
Nov.	4.55	0.99	5.54(17)	4.53	1.12	5.65(12)	5.28	0.86	6.14(14)			6.00e
Dec.	1.33	1.27	2.60(13)	1.22	1.57	2.79(9)	2.35	2.20	4.55(8)	1.59	1.56	3.15(10)
Total	33.73	4.19	37.92	32.37	3.75	36.12	34.83	5.91	40.74	37.24	3.05	40.29

e - estimated

Table 3c. 1970 Data: Monthly Precipitation Summary - Venison Creek Drainage Basin

Month (1970)	Station - Precipitation (inches)											
	Langton			Mabee			Morston			Walsingham		
	Rain	Snow	Total	Rain	Snow	Total	Rain	Snow	Total	Rain	Snow	Total
Jan.	0.50	1.47	1.97(16)	0.21	1.80	2.02(11)	0.25	3.10	3.35(11)	0.38	2.10	2.48(11)
Feb.	0.26	0.61	0.87(12)	0.56	1.04	1.60(12)	0.55	1.60	2.15(10)	1.41	0.54	1.95(6)
Mar.	2.17	-	2.17(14)	4.13	-	4.13(9)	3.39	-	3.39(10)	3.44	-	3.44(9)
Apr.	3.36	-	3.36(12)	4.52	-	4.52(11)	4.14	-	4.14(11)	4.53	-	4.53(10)
May	1.53	-	1.53(12)	1.54	-	1.54(13)	1.71	-	1.71(14)	1.46	-	1.46(12)
June	2.22	-	2.22(11)	2.20	-	2.20(12)	2.71	-	2.71(8)	3.06	-	3.06(9)
July	2.63	-	2.63(10)	3.55	-	3.55(11)	2.32	-	2.32(10)	2.28	-	2.28(8)
Aug.	1.27	-	1.27(11)	1.19	-	1.19(8)	1.01	-	1.01(9)	1.05	-	1.05(7)
Sept.	3.65	-	3.65(11)	2.91	-	2.91(10)	3.49	-	3.49(14)	4.43	-	4.43(9)
Oct.	5.88	-	5.88(13)	4.79	-	4.79(13)	5.83	-	5.83(13)	6.31	-	6.31(13)
Nov.	4.67	1.05	5.72(18)	4.47	1.49	5.96(14)	5.08	0.95	6.03(16)	4.94	0.06	5.00(14)
Dec.			4.00e	1.28	2.38	3.66(10)	1.31	3.10	4.41(12)	1.31	1.90	3.21(12)
Total	32.15	3.13	35.28	31.33	6.71	38.04	31.81	8.75	40.56	34.64	4.60	39.24

e - estimated

Table 3d. 1971 Data: Monthly Precipitation Summary - Venison Creek Drainage Basin

Month (1971)	Langton Rain	Langton Snow	Langton Total	Mabee Rain	Mabee Snow	Mabee Total	Morston Rain	Morston Snow	Morston Total	Walsingham Rain	Walsingham Snow	Walsingham Total
Jan.			1.5e	0.11	1.64	1.75(11)	0.17	1.30	1.47(10)	0.5e	1.0e	1.5e
Feb.	1.53	1.79	3.32(17)	1.5e	1.5e	3.0e	1.90	1.25	3.15(11)	2.0e	1.0e	3.0e
Mar.	0.51	1.13	1.64(12)	0.60	1.06	1.66(6)	0.35	1.22	1.57(7)	3.00	0.91	3.91(8)
Apr.	1.38	0.21	1.59(10)	1.62	0.11	1.73(8)	1.55	0.20	1.75(7)	1.90	-	1.90(8)
May	2.10	-	2.10(7)	1.67	-	1.67(8)	2.10	-	2.10(7)	2.43	-	2.43(7)
June	1.61	-	1.61(6)	1.40	-	1.40(9)	1.30	-	1.30(9)	2.06	-	2.06(7)
July	1.57	-	1.57(8)	1.51	-	1.51(11)	1.32	-	1.32(8)	2.29	-	2.29(5)
Aug.	3.51	-	3.51(8)	3.22	-	3.22(10)	2.58	-	2.58(8)	1.82	-	1.82(6)
Sept.	2.11	-	2.11(13)	2.51	-	2.51(10)	2.30	-	2.30(13)	1.93	-	1.93(5)
Oct.	1.82	-	1.82(9)	1.87	-	1.87(10)	1.91	-	1.91(8)	2.40	-	2.40(9)
Nov.	2.2e	0.5e	2.7e	1.56	0.56	2.12(10)	2.43	0.90	3.33(11)	2.55	0.30	2.85(10)
Dec.	3.4e	0.6e	4.0e	3.82	0.33	4.15(15)	4.26	0.80	5.06(11)	3.96	0.60	4.56(15)
Total	23.64	4.23	27.87	21.39	5.20	26.59	27.15	5.67	27.82	26.84	3.81	30.65

Station - Precipitation (inches)

e - estimated

Table 4. Summary of Selected Areal Average Daily Precipitation - Venison Creek Basin

Date 1968	Station - Precipitation (0.38 inch $\leq \overline{X}$ <1.00 inch)				
	Langton	Mabee	Morston	Walsingham	Average
Jan.29	0.96	0.97	1.10	0.84	0.97
Feb. 1	0.56	0.62	0.48	0.44	0.53
Mar. 15	0.45	0.38	0.50	0.60	0.48
Mar. 22	0.38	0.52	0.40	0.36	0.42
Apr. 23	0.66	0.37	0.59	0.85	0.62
May 9	0.57	0.62	0.66	0.36	0.55
May 16	0.73	0.52	0.54	0.52	0.58
May 19	0.45	0.29	0.43	0.37	0.39
June 29	0.68	0.28	0.35	0.34	0.41
July 5	0.44	1.05	0.23	0.15	0.47
Aug. 19	0.34	0.56e	0.85	0.71	0.62
Sept. 1	0.41	0.55	0.42	0.25	0.41
Oct. 2	0.57	0.71	0.51	0.49	0.57
Oct. 18	0.77	1.04	0.82	0.82	0.86
Oct. 28	0.79	0.41	1.31	0.74	0.81
Nov. 9	0.30	0.24	0.50	0.59	0.41
Nov. 15	0.59	0.63	0.69	0.57	0.62
Dec. 4	0.57	0.56	0.55	0.50	0.55
Dec. 24	0.64	0.20	0.40	0.40	0.41

e - estimated

Table 4. Summary of Selected Areal Average Daily
(cont'd.) Precipitation -Venison Creek Basin

Date 1969	Station - Precipitation ($0.38 \text{ inch} \leq \overline{X} < 1.00 \text{ inch}$)				
	Langton	Mabee	Morston	Walsingham	Average
Jan. 17	0.75	0.96	1.00	1.10	0.95
Mar.24	0.74	0.67	0.60	0.90	0.73
Apr. 1	0.65	0.67	0.35	0.82	0.62
Apr. 15	0.43	0.61	0.55	0.69	0.57
Apr. 17	0.86	1.25	0.25	0.56	0.73
Apr. 18	0.75	0.49	0.82	1.26	0.83
Apr. 21	0.71	0.51	0.65	0.19	0.52
May 7	0.67	0.55	0.75	0.86	0.71
May 10	0.67	0.69	0.72	0.76	0.71
June 15	0.53	0.53	0.50	0.64	0.55
July 4	0.65	0.66	0.65	0.95	0.73
July 10	0.27	0.08	0.61	1.50	0.62
July 18	0.60	0.18	0.78	0.69	0.54
July 26	0.45	0.41	0.49	0.91	0.57
July 27	0.60	0.74	0.51	0.45	0.58
July 28	0.56	0.42	0.74	0.62	0.59
Aug. 16	1.53	0.25	0.26	0.29	0.58
Sept. 16	0.62	0.53	0.52	0.68	0.59
Sept. 23	0.43	0.61	0.36	0.55	0.49
Oct. 2	0.42	0.34	0.29	0.47	0.38
Oct. 13	0.37	0.51	0.39	0.35	0.41
Oct. 21	0.56	0.47	0.55	0.55	0.53
Nov. 3	0.62	0.43	0.76	0.63e	0.61
Nov. 4	0.24	0.67	0.24	0.41e	0.39
Nov. 13	0.37	0.51	0.39	0.35	0.75
Nov. 15	0.53	0.54	0.16	0.43	0.42
Nov. 18	0.83	0.73	0.80	0.81e	0.79
Dec. 10	0.84	0.79	1.00	0.90e	0.88

Table 4. Summary of Selected Areal Average Daily
(cont'd.) Precipitation Venison Creek Basin

Date 1970	Station - Precipitation (0.38 inch $\leq \bar{X} < 1.00$ inch)				
	Langton	Mabee	Morston	Walsingham	Average
Jan. 7	0.27	0.21	0.60	0.50	0.40
Jan. 17	0.12	0.36	0.40	0.71	0.40
Mar. 3	0.25	0.90	0.50	0.35	0.50
Mar. 4	0.66	0.82	0.50	0.65	0.66
Mar. 19	0.26	0.86	0.50	0.37	0.50
Mar. 28	0.22	1.03	0.78	0.40	0.61
Apr. 19	0.48	0.45	0.43	0.47	0.46
Apr. 28	0.87	0.76	1.34	0.99	0.99
June 12	0.18	0.23	0.51	0.71	0.41
June 14	0.47	0.44	0.40	0.43	0.44
June 17	0.25	0.20	0.50	0.74	0.42
June 26	0.62	0.64	0.61	0.48	0.59
July 3	0.43	0.39	0.50	0.41	0.43
July 14	0.71	1.48	0.43	0.36	0.75
July 19	0.52	0.69	0.51	0.30	0.51
Sept. 2	0.31	0.47	0.66	0.53	0.49
Sept. 8	0.71	0.12	0.36	0.53	0.43
Sept. 17	0.82	0.55	0.57	0.99	0.73
Sept. 24	0.48	0.30	0.75	0.78	0.58
Sept. 26	0.33	0.41	0.25	0.87	0.47
Oct. 2	0.52	0.70	0.38	0.30	0.48
Oct. 12	0.77	0.76	0.68	0.71	0.73
Oct. 22	1.29	0.19	1.20	0.33	0.75
Oct. 29	0.96	0.81	1.05	1.10	0.98
Oct. 30	0.45	0.40	0.50	0.43	0.45
Nov. 2	0.44	0.31	0.39	0.38	0.38
Nov. 9	0.46	0.48	0.44	0.36	0.44
Nov. 20	0.35	0.37	0.31	0.50	0.38
Nov. 23	0.52	0.64	0.40	0.03	0.40
Nov. 27	0.73	0.78	0.86	0.79	0.79
Dec. 3	0.75e	1.01	0.58	0.48	0.71
Dec. 10	0.83e	0.58	1.00	0.80	0.80
Dec. 11	0.56e	0.66	0.60	0.30	0.53
Dec. 16	0.71e	0.44	1.00	0.60	0.69
Dec. 26	0.43e	0.48	0.40	0.30	0.40

Table 4. (cont'd.) Summary of Selected Areal Average Daily Precipitation - Venison Creek Basin

Date 1971	Station - Precipitation (0.38 inch $\leq \overline{X} < 1.00$ inch)				
	Langton	Mabee	Morston	Walsingham	Average
Feb. 4	0.53	0.5e	0.50	0.5e	0.51
Feb. 8	0.43	0.5e	0.50	0.5e	0.48
Feb. 22	0.54	0.5e	0.50	0.5e	0.51
Mar. 6	0.47	0.51	0.25	0.43	0.42
Mar. 19	0.41	0.66	0.30	0.98	0.59
Apr. 1	0.69	0.85	0.75	0.56	0.71
Apr. 13	0.47	0.47	0.50	0.59	0.51
June 2	0.49	0.40	0.43	0.37	0.42
June 7	0.49	0.38	0.48	0.55	0.48
July 24	0.25	0.32	0.42	0.66	0.47
Aug. 10	1.05	0.94	0.80	0.44	0.81
Aug. 26	0.79	0.82	0.62	0.45	0.67
Sept. 20	0.73	0.89	0.70	0.70	0.76
Oct. 9	0.55	0.67	0.62	0.56	0.60
Nov. 20	0.5e	0.35	0.55	0.23	0.51
Nov. 29	0.5e	0.48	0.60	0.76	0.59
Dec. 30	0.02	0.35	1.00	0.25	0.41

Table 4. Summary of Selected Areal Average Daily
(cont'd.) Precipitation - Venison Creek Basin

	Station - Precipitation (1.00 inch $\leq \overline{X} <$ 2.00 inch)				
Date	Langton	Mabee	Morston	Walsingham	Average
Jan. 13/68	0.70	1.17	1.00	1.32	1.05
Apr. 3/68	1.06	0.98	1.10	1.20	1.09
Nov. 28/68	1.52	1.55	1.60	1.70	1.59
Dec. 27/68	0.96	1.00	0.50	1.65	1.03
Jan. 29/69	1.05	1.70	0.85	1.10	1.18
Jan. 30/69	1.00	0.89	1.05	1.10	1.01
Nov. 1/69	1.30	1.48	1.31	1.42e	1.38
Dec. 7/69	1.00	0.90	1.75	1.11	1.19
Apr. 1/70	0.76	1.80	0.75	1.18	1.12
Apr. 4/70	1.14	1.14	1.25	1.29	1.21
Nov. 3/70	1.73	1.71	1.85	1.77	1.77
May 24/71	1.79	1.49	1.85	1.87	1.75

Table 4. (cont'd.) Summary of Selected Areal Average Daily Precipitation - Venison Creek Basin

Date	Station - Precipitation ($\overline{X} \geq 2.00$ inches)				
	Langton	Mabee	Morston	Walsingham	Average
May 18/69	2.33	2.27	2.35	1.86	2.20
June 25/68	3.69	3.70	3.75	3.88	3.76
Aug. 5/68	1.82	1.90e	1.64	2.70	2.02
Sept. 5/68	2.50	2.35	3.05	2.99	2.72

Table 5a. 1968 Data: Summary of Recording Precipitation Data*- Frequency of Storm Duration at Langton, Venison Creek Basin

	1 - Hour			1 - 3 Hours			3 - 6 Hours			6 - 12 Hours			12 - 18 Hours			18 - 24 Hours			Total	
Year 1968	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Depth (in.)
Jan.	3	0.03	0.01	1	0.14	0.14	2	0.59	0.45	1	0.36	0.36	-			-			7	1.12
Feb.	3	0.04	0.02	1	0.18	0.18	1	0.28	0.28	-			-			-			5	0.50
Mar.	7	0.07	0.01	5	0.23	0.09	1	0.07	0.07	-			-			1		0.64	13	1.01
Apr.	5	0.38	0.32	7	0.71	0.34	-			1	1.05	1.05	-			-			13	2.14
May	12	0.48	0.19	8	0.92	0.55	4	1.69	0.66	2	0.22	0.12	-			-			26	3.31
June	10	0.37	0.13	10	2.01	0.68	1	0.26	0.26	-			1	3.56	3.56	-			22	6.20
July	5	0.14	0.06	2	0.60	0.41	1	0.43	0.43	-			-			-			8	1.17
Aug.	12	0.54	0.30	6	3.00	1.79	1	0.46	0.46	-			-			-			19	4.00
Sept.	11	0.48	0.23	4	0.32	0.17	-			2	2.96	1.57	-			-			17	3.76
Oct.	8	0.12	0.02	5	0.48	0.18	5	1.59	0.56	-			1	0.70	0.70	-			19	2.87
Nov.	2	0.02	0.01	5	0.61	0.38	1	0.11	0.11	2	1.31	1.11	1	0.91	0.91	-			11	2.96
Dec.	2	0.02	0.01	3	0.10	0.05	4	0.96	0.38	1	0.41	0.41	1	0.52	0.52	-			11	2.01

(-) - Nil.

* - The values for total monthly precipitation in the series of tables 5 and 6 do not necessarily equate to those for the standard rain gauge at Langton shown in Table 3. During the winter months, snow storm events are not usually recorded by the type of automatic gauges used and in addition, due to incomplete or missing data, all possible storm events are not included in the series of tables 5 and 6.

Table 5b. 1969 Data: Summary of Recording Precipitation Data* - Frequency of Storm Duration at Langton, Venison Creek Basin

	1 - Hour			1 - 3 Hours			3 - 6 Hours			6 - 12 Hours			12 - 18 Hours			18 - 24 Hours			Total	
Year 1969	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Depth (in.)
Jan.	1	0.01	0.01	4	0.09	0.03	1	0.06	0.06	-			-			1	1.93	1.93	6	2.09
Feb.																				M
Mar.	5	0.10	0.05	4	0.40	0.25	-			2	0.78	0.55	1	0.26	0.26	-			12	1.54
Apr.	4	0.06	0.03	8	0.69	0.21	3	0.54	0.28	3	2.49	1.14	-			-			18	3.78
May	11	0.19	0.07	7	0.50	0.18	2	0.14	0.07	2	1.43	0.76	-			1	2.40	2.40	23	4.66
June	19	0.31	0.04	8	0.82	0.17	5	1.54	0.80	2	0.78	0.53	-			-			34	3.45
July	17	1.10	0.37	9	2.17	0.51	-			1	0.56	0.56	-			-			27	3.83
Aug.	5	0.10	0.04	2	1.51	1.31	-			-			-			-			7	1.61
Sept.	2	0.09	0.08	4	0.32	0.15	1	0.10	0.10	2	0.78	0.42	-			-			9	1.29
Oct.	5	0.05	0.01	4	0.53	0.21	6	1.98	0.41	-			-			-			15	2.56
Nov.	8	0.11	0.03	4	0.56	0.29	3	0.79	0.43	2	1.20	0.64	1	0.66	0.66	1	1.26	1.26	19	4.58
Dec.																				M

M - Missing Data

(-) Nil

Table 5c. 1970 Data: Summary of Recording Precipitation Data* - Frequency of Storm Duration at Langton, Venison Creek Basin

	1 - Hour			1 - 3 Hours			3 - 6 Hours			6 - 12 Hours			12 - 18 Hours			18 - 24 Hours			Total	
Year 1970	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Depth (in.)
Jan.																				M
Feb.																				M
Mar.																				M
Apr.	9	0.17	0.04	3	0.92	0.83	5	1.24	0.41	-			-			-			17	2.33
May																				M
June	5	0.14	0.05	5	0.69	0.25	2	0.79	0.47	1	0.62	0.62	-			-			13	2.24
July	10	0.41	0.26	9	1.70	0.45	2	0.52	0.36	-			-			-			21	2.63
Aug.	13	0.77	0.32	6	0.53	0.22	-			-			-			-			14	1.30
Sept.	10	0.33	0.10	11	2.19	0.34	2	1.23	0.75	-			-			-			23	3.75
Oct.	13	0.74	0.50	9	0.64	0.23	4	0.26	0.09	3	2.23	1.24	1	0.96		1	1.10	1.10	30	5.93
Nov.	14	0.20	0.03	3	0.23	0.17	5	1.08	0.40	3	1.04	0.50	-			1	2.14	2.14	25	4.69
Dec.	5	0.08	0.02	-			2	0.19	0.14	1	0.57	0.57	-			-			8	0.84

M - Missing Data

(-) Nil.

Table 5d. 1971 Data: Summary of Recording Precipitation Data*- Frequency of Storm Duration at Langton, Venison Creek Basin

	1 - Hour			1 - 3 Hours			3 - 6 Hours			6 - 12 Hours			12 - 18 Hours			18 - 24 Hours			Total	
Year 1971	No. of Storms	Ppt. (in.)	Max. Inten. (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Ppt. (in.)	Max. Storm (in.)	No. of Storms	Depth (in.)
Jan.																				M
Feb.																				M
Mar.				1	0.03	0.03				1	0.47	0.47	-			-			2	0.50
Apr.	5	0.09	0.03	1	0.03	0.03	1	0.11	0.11	1	0.47	0.47	-			-			8	0.70
May	5	0.18	0.12	2	0.11	0.06	-			-			-			-			7	0.29
June	3	0.11	0.09	-			-			-			-			-			3	0.11
July	3	0.17	0.14	3	0.49	0.43	3	0.91	0.36	-			-			-			9	1.57
Aug.	6	0.32	0.15	1	1.10	1.10	3	2.09	1.02	-			-			-			10	3.51
Sept.	5	0.40	0.30	6	0.49	0.15	2	0.48	0.34	1	0.74	0.74	-			-			14	2.11
Oct.	7	0.25	0.10	2	0.54	0.42	4	0.49	0.17	1	0.54	0.54	-			-			14	1.82
Nov.																				M
Dec.																				M

M - Missing Data

(-) Nil.

Table 6a. 1968 Data: Summary of Recording Precipitation Data* - Frequency of Hourly Storm Intensity at Langton, Venison Creek Basin

	(0.01 - 0.09) in./hr.			(0.10 - 0.19) in./hr.			(0.20 - 0.49) in./hr.			(0.50 - 0.99) in./hr.			(1.00 - 2.00) in./hr.			Total	
Year 1968	No.of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No.of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No.of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No.of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No.of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No.of Hours	Depth (in.)
Jan.	21	0.81	0.09				1	0.32	0.32	-			-			22	1.12
Feb.	9	0.37	0.08	1	0.13	0.13	-			-			-			10	0.50
Mar.	45	1.01	1.01	-	-		-			-			-			45	1.01
Apr.	21	0.51	0.09	4	0.62	0.18	3	1.01	0.42	-			-			28	2.14
May	62	1.29	0.08	4	0.62	0.19	6	1.40	0.27	-			-			72	3.31
June	31	0.85	0.08	9	1.15	0.19	6	1.74	0.42	4	2.46	0.66	-			50	6.20
July	13	0.45	0.09	1	0.15	0.15	2	0.57	0.34	-			-			16	1.17
Aug.	21	0.37	0.07	6	0.92	0.17	1	0.30	0.30	3	2.41	0.90	-			31	4.00
Sept.	27	0.93	0.09	2	0.30	0.18	5	1.27	0.35	2	1.26	0.64	-			36	3.76
Oct.	51	1.41	0.09	12	1.46	0.16	-			-			-			63	2.87
Nov.	44	1.30	0.08	8	1.06	0.18	2	0.60	0.33	-			-			54	2.96
Dec.	48	1.88	0.09	1	0.13	0.13	-			-			-			49	2.01

(-) - Nil.

Table 6b. 1969 Data: Summary of Recording Precipitation Data* - Frequency of Hourly Storm Intensity at Langton, Venison Creek Basin

	(0.01 - 0.09) in./hr.			(0.10 - 0.19) in./hr.			(0.20 - 0.49) in./hr.			(0.50 - 0.99) in./hr.			(1.00 - 2.00) in./hr			Total	
Year 1969	No. of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No. of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No. of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No. of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No. of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No. of Hours	Depth (in.)
Jan.	36	1.04	0.09	9	1.05	0.17	-			-			-			45	2.09
Feb.																	M
Mar.	42	1.20	0.09	1	0.10	0.10	1	0.24	0.24	-			-			-	1.54
Apr.	46	1.17	0.07	18	2.41	0.19	1	0.20	0.20	-			-			44	3.78
May	56	1.54	0.09	9	1.12	0.16	8	2.00	0.30	-			-			65	4.66
June	65	1.86	0.09	9	1.23	0.19	1	0.36	0.36	-			-			73	3.45
July	31	0.93	0.07	7	1.03	0.19	4	1.37	0.37	1	0.50	0.50	-			43	3.83
Aug.	6	0.14	0.04	1	0.16	0.16	1	0.36	0.36	1	0.95	0.95	-			9	1.61
Sept.	27	0.92	0.09	3	0.37	0.13	-			-			-			30	1.29
Oct.	36	1.03	0.09	9	1.21	0.18	1	0.32	0.32	-			-			46	2.56
Nov.	70	2.52	0.09	14	1.84	0.18	1	0.22	0.22	-			-			85	4.58
Dec.																	M

M - Missing Data

(-) Nil.

Table 6c. 1970 Data: Summary of Recording Precipitation Data* - Frequency of Hoursly Storm Intensity at Langton, Venison Creek Basin

	(0.01 - 0.09) in./hr.			(0.10 - 0.19) in./hr.			(0.20 - 0.49) in./hr.			(0.50 - 0.99) in./hr.			(1.00 - 2.00) in./hr.			Total	
Year 1970	No.of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No. of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No. of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No.of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No.of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No.of Hours	Depth (in.)
Jan.																	M
Feb.																	M
Mar.																	M
Apr.	31	0.96	0.08	4	0.54	0.16	3	0.86	0.36	-			-			38	2.33
May				-			-										M
June	25	0.87	0.09	5	0.73	0.19	3	0.64	0.22	-			-			33	2.24
July	32	1.06	0.09	4	0.54	0.17	3	1.08	0.42	-			-			39	2.68
Aug.	21	0.44	0.09	1	0.13	0.13	3	0.73	0.32	-			-			25	1.30
Sept.	35	1.17	0.09	9	1.20	0.19	4	1.38	0.48	-			-			48	3.75
Oct.	98	3.50	0.09	8	0.98	0.17	3	0.95	0.47	1	0.50	0.50	-			110	5.95
Nov.	76	2.69	0.09	15	2.00		-			-			-			91	4.69
Dec.	19	0.33	0.06	2	0.28	0.15	1	0.23	0.23	-			-			22	0.84

M - Missing Data

(-) Nil.

Table 6d. 1971 Data - Summary of Recording Precipitation Data* - Frequency of Hourly Storm Intensity at Langton, Venison Creek Basin

	(0.01 - 0.09) in./hr.			(0.10 - 0.19) in./hr.			(0.20 - 0.49) in./hr.			(0.50 - 0.99) in./hr.			(1.00 - 2.00) in./hr.			Total	
Year 1971	No.of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No.of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No.of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No. of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No.of Hours	Ppt. (in.)	Max. Inten. (in/hr)	No.of Hours	Depth (in.)
Jan.																	M
Feb.																	M
Mar.	13	0.50	0.09				-			-			-			13	0.50
Apr.	20	0.56	0.07	1	0.14	0.14	-			-			-			21	0.70
May	8	0.17	0.05	1	0.12	0.12	-			-			-			9	0.29
June	3	0.11	0.09	-			-			-			-			3	0.11
July	21	0.75	0.09	5	0.62	0.18	1	0.20	0.20	-			-			27	1.57
Aug.	13	0.49	0.09	6	0.77	0.18	2	0.72	0.39	2	1.53	0.97	-			23	3.51
Sept.	28	0.84	0.09	7	0.97	0.18	1	0.30	0.30	-			-			36	2.11
Oct.	34	1.20	0.09	3	0.38	0.17	1	0.24	0.24	-			-			38	1.82
Nov.																	M
Dec.																	M

M - Missing Data

(-) Nil

Table 7. Monthly Precipitation Summary for Selected Regional Long-Term Index Stations in Southern Ontario

1968	STATION - PRECIPITATION (in.)							
	Delhi CDA.	St. Williams	Tillsonburg	London-A	Woodstock	Port Dover	Brantford	Port Stanley
Jan.	2.79	3.86	3.27	4.36	3.99	4.08	2.73	4.22
Feb.	1.25	1.58	1.82e	3.26	2.46	1.27	1.57	0.92
Mar.	2.20	2.28	2.13e	2.20	2.38	1.96e	1.48	1.87
Apr.	1.72	2.40	1.70	1.84	1.46	2.20	1.59	1.86
May	2.99	2.82	2.47	2.67	2.68	2.72	3.01	3.05
June	6.36	5.51	5.71	5.72	5.38	6.15	4.66	5.21
July	1.60	0.87	1.64e	3.63	1.79	1.28	0.76	1.67e
Aug.	3.00	4.06	3.96	2.94	2.19	3.43	4.36	4.56
Sept.	3.90	3.19	4.23	4.33	3.36	3.40	3.14	4.26
Oct.	2.69	3.73	2.87	3.60	2.45	3.44	2.27	2.95
Nov.	3.73	5.33	4.33	4.31	4.17	4.76	3.61	3.18
Dec.	3.50	4.59	4.79	5.01	2.86	3.43	1.82	3.11
Total	35.73	40.22	38.92	43.87	35.17	38.16	31.00	36.86

e - estimated

Table 7. Monthly Precipitation Summary for Selected Regional Long-Term Index Stations in Southern Ontario
(cont'd)

	STATION - PRECIPITATION (in.)							
1969	Delhi CDA.	St. Williams	Tillsonburg	London-A	Woodstock	Port Dover	Brantford	Port Stanley
Jan.	4.80	5.20	4.49	4.41	3.20	4.00	2.92	2.48
Feb.	0.55	1.00	0.66	1.18	0.89	0.50e	0.71	0.77
Mar.	1.94	2.35	2.01	2.29	2.04	1.39	1.78	1.66
Apr.	4.87	4.92	4.88e	4.03	4.31	5.28	3.85	4.37
May	5.35	3.89	4.58	4.28	3.62	3.74	4.00	5.74
June	2.99	3.65	2.99	3.37	2.35	3.73	3.23e	2.62
July	3.50	5.39	3.45	2.03	1.54	3.97	4.05	6.09
Aug.	0.33	0.20	0.76	0.78	0.60	1.54	0.13	0.18
Sept.	1.07	1.16	1.16	1.01	1.09	1.44	0.95	1.15
Oct.	3.00	2.73	3.80	3.55	3.61	2.53	2.60	2.47
Nov.	4.33	7.84	4.81	4.76	4.57	4.65	2.70	4.66
Dec.	2.79	3.49	3.78	2.59	1.81	3.60	2.02	3.01
Total	35.52	41.82	38.27	34.28	29.63	36.37	28.94	35.20

Table 7. (cont'd) Monthly Precipitation Summary for Selected Regional Long-Term Index Stations in Southern Ontario

1970	STATION - PRECIPITATION (in.)							
	Delhi CDA.	St. Williams	Tillsonburg	London-A	Woodstock	Port Dover	Brantford	Port Stanley
Jan.	1.31	4.24	2.18	1.66	0.99	0.95	1.44	1.44
Feb.	1.36	2.16	1.31	1.41	1.01e	1.15	1.34	0.64
Mar.	2.08	2.46	1.95	2.18	1.96	3.14	1.54	2.03
Apr.	3.12	3.27	3.69	3.43	3.52	2.74	3.45	2.87
May	1.58	2.02	1.64	2.49	2.58	1.21	2.34	2.09
June	2.15	2.16	1.96e	2.68	2.52	2.04	2.33	3.37
July	5.16	1.89	4.66	4.34	5.48	3.33	3.56	2.68
Aug.	1.31	2.23	0.73	0.83	1.33	1.77	1.53	1.39
Sept.	3.04	5.40	3.00	2.97	3.06	5.64	4.80	2.95
Oct.	4.36	3.95	4.55	4.26	2.83	4.97	2.94	4.17
Nov.	5.24	5.99	4.68	5.12	3.44	3.79	2.12	3.22
Dec.	3.39	3.94	2.85	3.72	2.58	3.52	3.10	2.75
Total	34.10	39.71	33.20	35.09	31.30	34.25	30.49	29.60

APPENDIX II

Results of Data Analyses

APPENDIX II

List of Figures

APPENDIX II

List of Tables

APPENDIX II

List of Tables

APPENDIX II

List of Tables

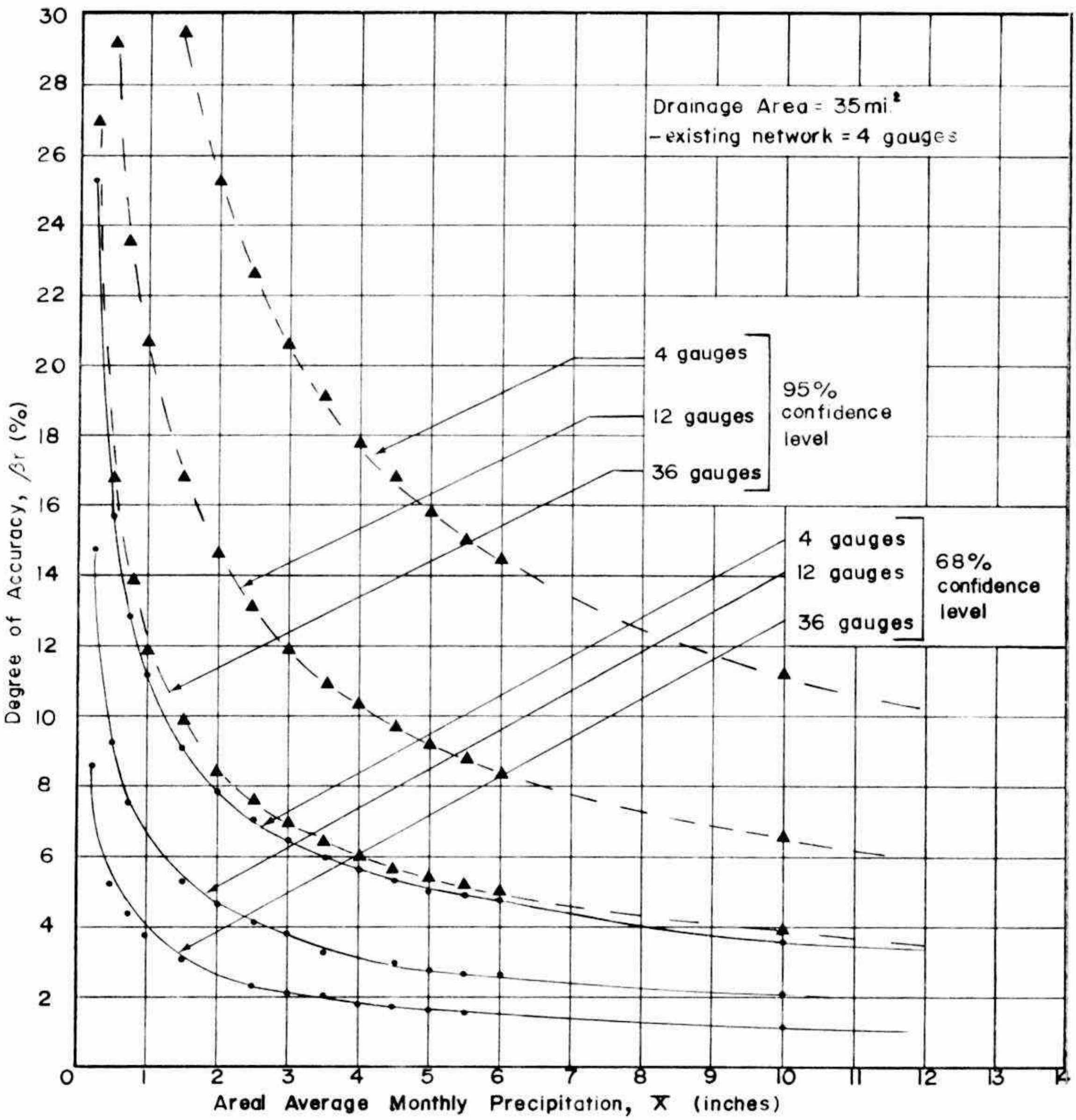

Figure 2. Confidence - Reliability Curves for Areal Average Monthly Precipitation with Various Gauge Network Density in Venison Creek Basin.

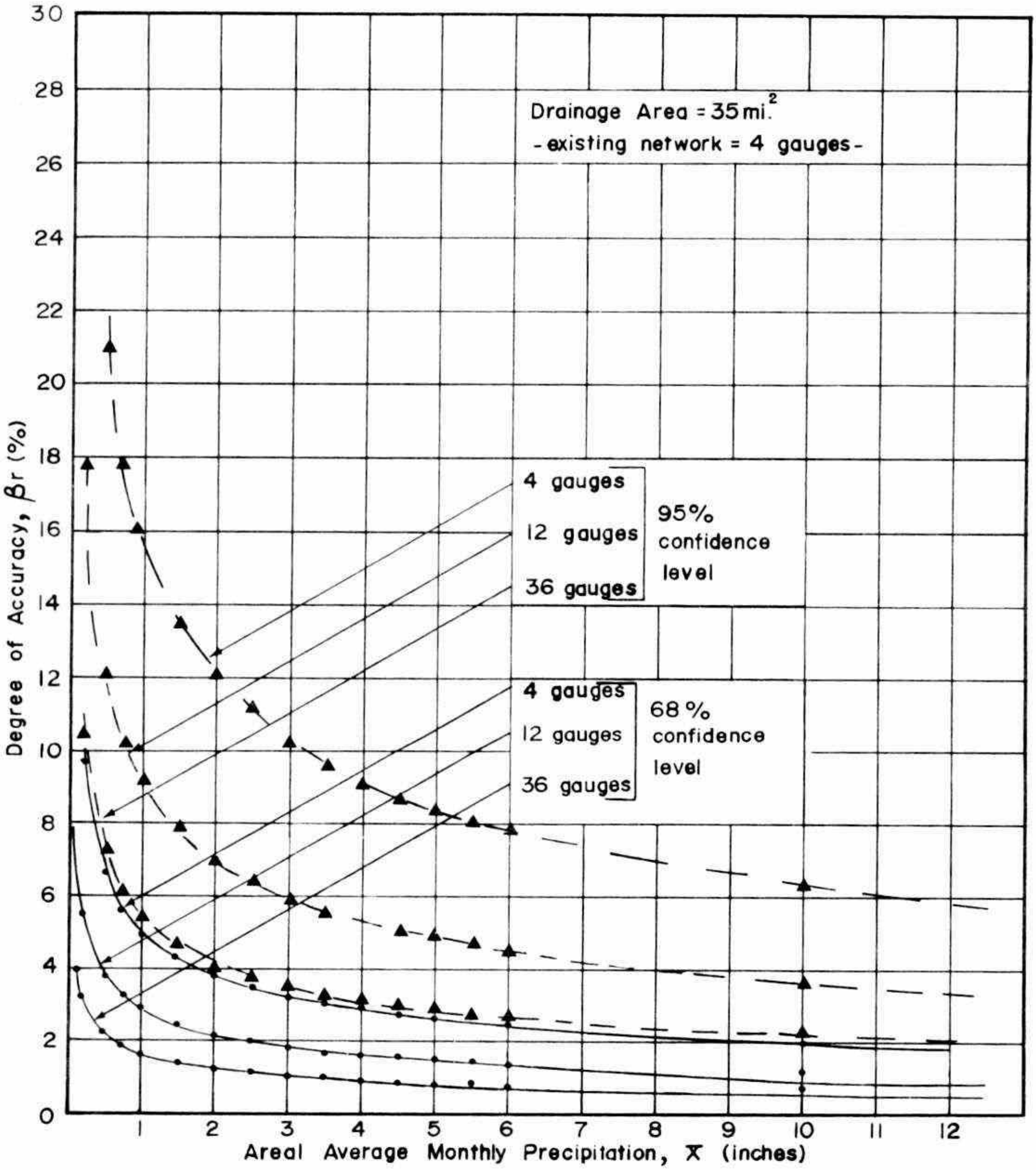

Figure 3. Confidence - Reliability Curves for Areal Average Monthly Precipitation with Various Gauge Network Density in Venison Creek Basin; (based on reduced standard errors).

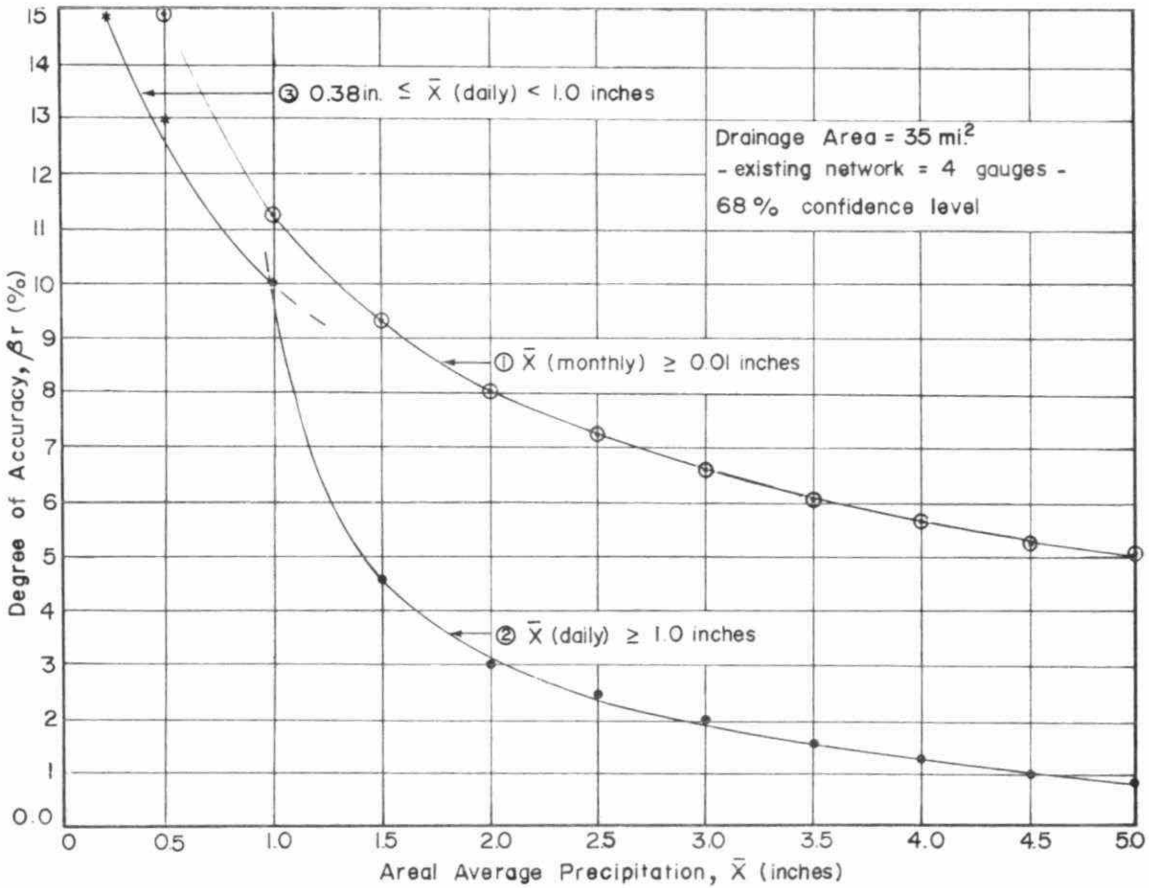

Figure 4. Confidence - Reliability Curves for Areal Average Precipitation with Different Accumulation Periods and Depths, Venison Creek Basin.

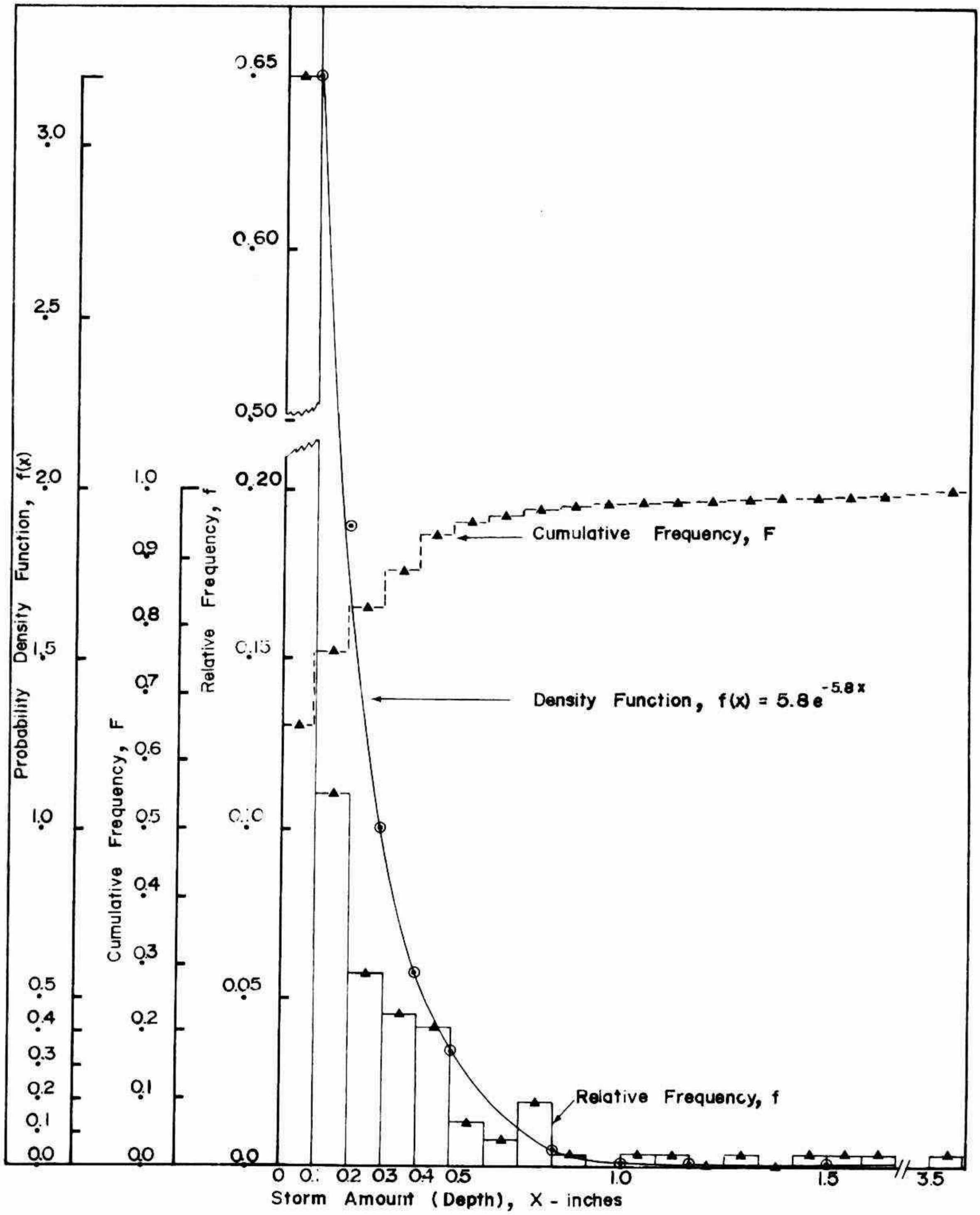

Figure 5. Frequency Distribution of Amounts for Summer Storm Events in Venison Creek Basin, 1968 to 1971 Data.

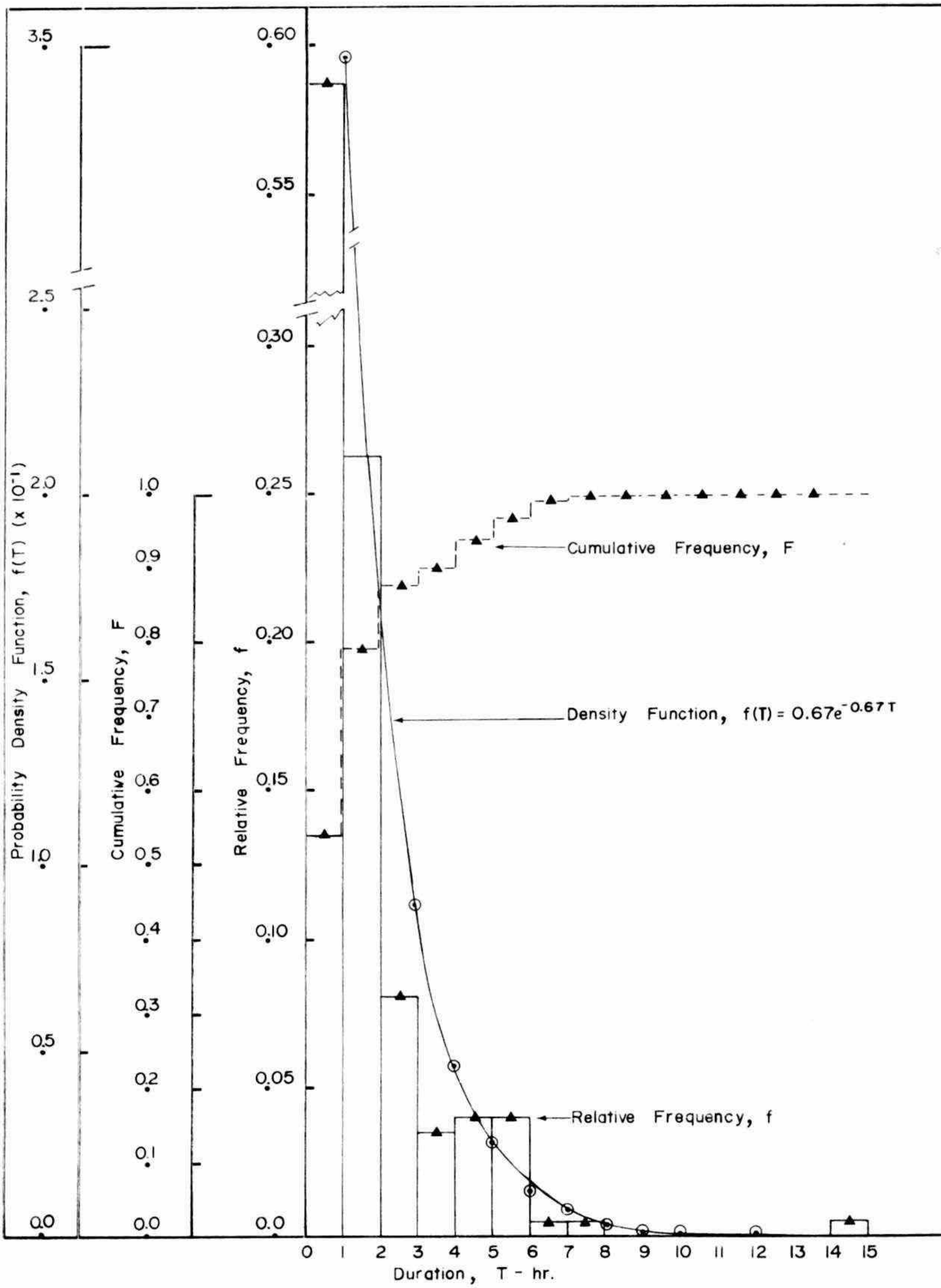

Figure 6. Frequency Distribution of Duration for Summer Storm Events in Venison Creek Basin, 1968 to 1971 Data.

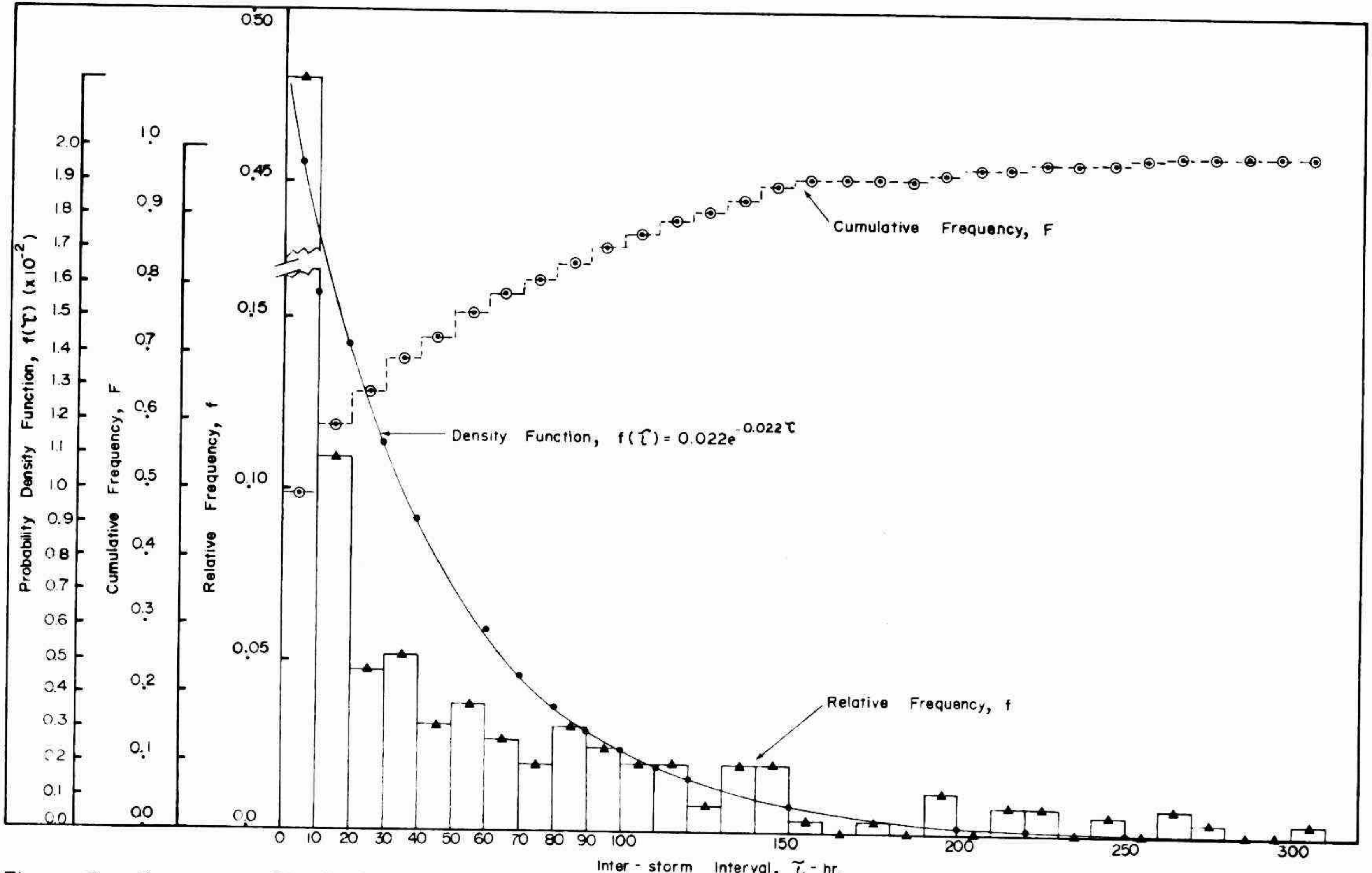

Figure 7. Frequency Distribution of Inter-storm Interval for Summer Storm Events in Venison Creek Basin, 1968 to 1971 Data.

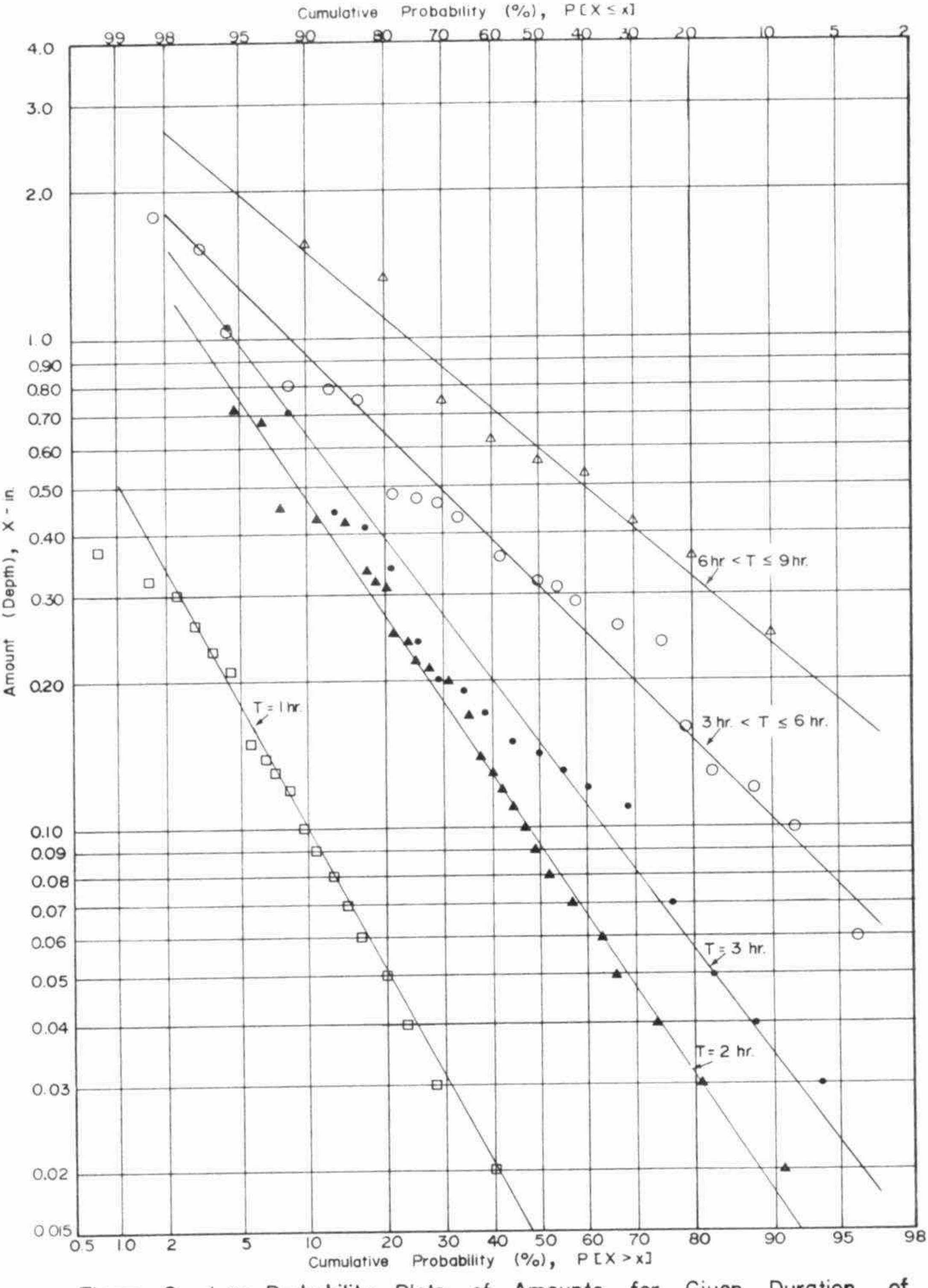

Figure 8. Log-Probability Plots of Amounts for Given Duration of Summer Storm Events in Venison Creek Basin, 1968 to 1971 Data.

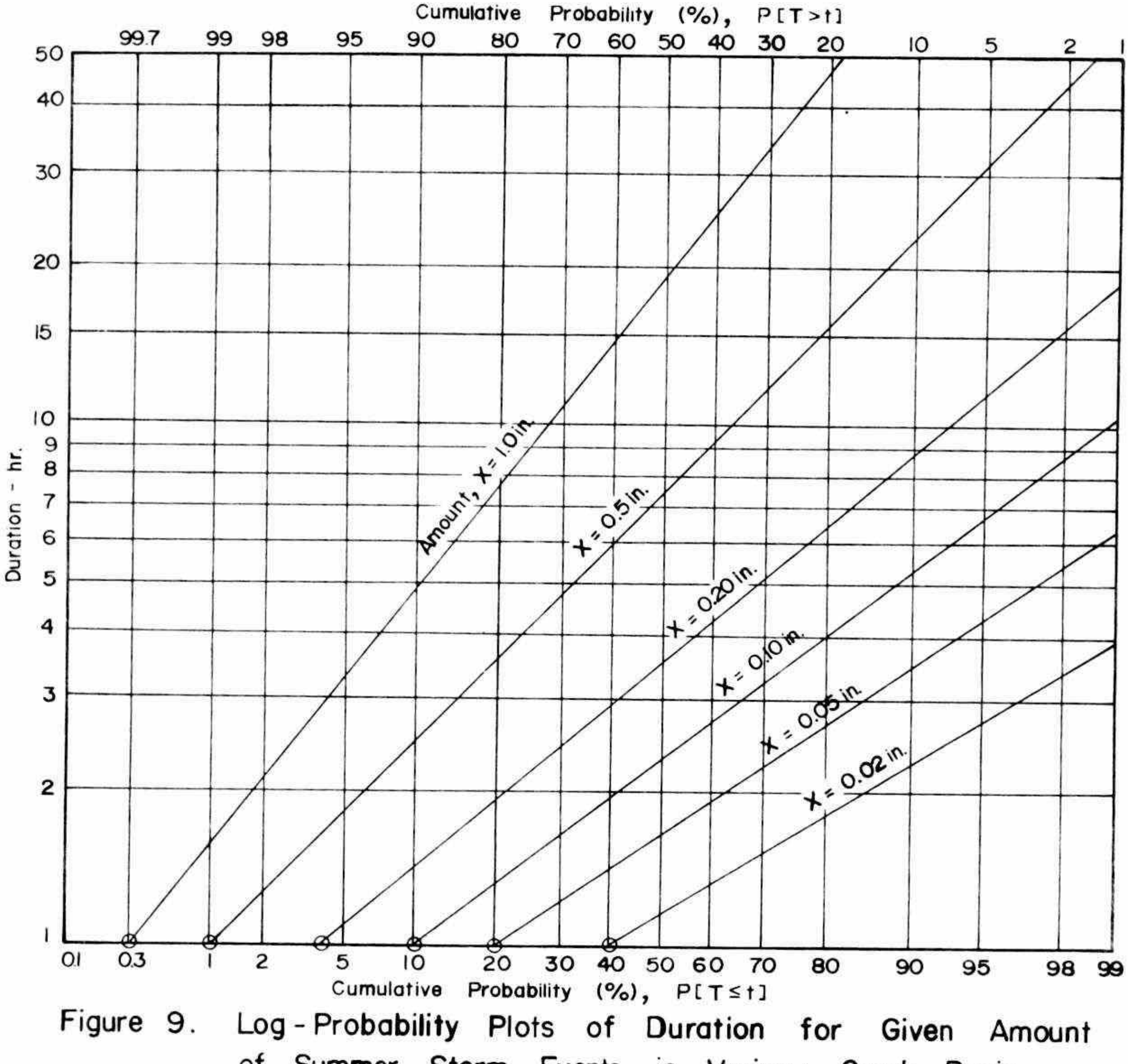

Figure 9. Log - Probability Plots of Duration for Given Amount of Summer Storm Events in Venison Creek Basin, 1968 to 1971 Data.

Table 8a. Average, Standard Deviation and Relative Standard Error of Monthly Precipitation in Venison Creek Basin - 1968 Data

Month (1968)	Average Precipitation* Thiessen Polygon Weighted (in.)	Average Precipitation* Arithmetic (in.)	Standard Deviation S (in.)	Relative Standard Error E_r (%)
Jan.	3.22	3.41	0.77	10.0
Feb.	0.98	1.04	0.33	13.7
Mar.	1.84	1.84	0.36	8.3
Apr.	2.08	2.09	0.34	7.4
May	2.80	2.88	0.36	5.4
June	5.92	6.04	0.16	1.1
July	1.25	1.23	0.58	20.1
Aug.	3.94	3.97	0.36	4.0
Sept.	4.04	4.07	0.28	3.1
Oct.	3.41	3.39	0.49	6.5
Nov.	3.34	4.35	0.74	7.7
Dec.	4.19	4.25	1.00	10.5
Annual	38.65	38.59	2.76	3.2

* 5-station average

Table 8b. Average, Standard Deviation and Relative Standard Error of Monthly Precipitation in Venison Creek Basin - 1969 Data

Month (1969)	Average Precipitation* Thiessen-Polygon Weighted (in.)	Average Precipitation* Arithmetic (in.)	Standard Deviation S (in.)	Relative Standard Error E_r (%)
Jan.	4.74	4.68	0.47	5.0
Feb.	0.48	0.57	0.11	9.5
Mar.	1.55	1.60	0.20	6.2
Apr.	5.16	5.17	0.47	4.5
May	5.05	5.10	0.51	5.0
June	2.97	2.96	0.13	2.2
July	4.31	4.42	1.36	15.3
Aug.	0.60	0.78	0.60	38.5
Sept.	1.38	1.40	0.09	3.4
Oct.	2.99	2.87	0.48	7.1
Nov.	5.90	5.84	0.29	2.5
Dec.	3.39	3.27	0.88	18.5
Annual	38.81	38.77	2.16	2.6

* 4-station average

Table 8c. Average, Standard Deviation and Relative Standard Error of Monthly Precipitation in Vension Creek Basin - 1970 Data

Month (1970)	Average Precipitation* Thiessen-Polygon Weighted (in.)	Average Precipitation* Arithmetic (in.)	Standard Deviation S (in.)	Relative Standard Error E_r (%)
Jan.	2.53	2.46	0.64	13.0
Feb.	1.77	1.64	0.56	17.2
Mar.	3.52	3.28	0.82	12.4
Apr.	4.27	4.14	0.55	6.7
May	1.57	1.56	0.11	3.4
June	2.56	2.55	0.42	8.2
July	2.79	2.70	0.59	10.9
Aug.	1.12	1.13	0.12	5.3
Sept.	3.52	3.62	0.63	8.6
Oct.	5.57	5.70	0.65	5.7
Nov.	5.75	5.68	0.47	4.2
Dec.	3.82	3.82	0.51	6.6
Annual	38.78	38.28	2.25	3.0

* 4-station average

Table 8d. Average, Standard Deviation and Relative Standard Error of Monthly Precipitation in Venison Creek Basin - 1971 Data

Month (1971)	Average Precipitation* Thiessen-Polygon Weighted (in.)	Average Precipitation* Arithmetic (in.)	Standard Deviation S (in.)	Relative Standard Error E_r (%)
Jan.	1.58	1.56	0.13	4.2
Feb.	3.01	3.12	0.15	2.4
Mar.	2.15	2.20	1.14	26.0
Apr.	1.77	1.74	0.13	3.9
May	2.02	2.08	0.31	7.5
June	1.55	1.60	0.34	10.5
July	1.65	1.67	0.43	12.7
Aug.	2.73	2.78	0.75	13.5
Sept.	2.27	2.21	0.25	5.7
Oct.	2.00	2.00	0.27	6.8
Nov.	2.72	2.75	0.50	9.1
Dec.	4.12	4.44	0.48	5.5
Annual	28.05	28.23	1.72	3.0

* 4-station average

Table 8e. Average. Standard Deviation and Relative Standard Error of Monthly Precipitation in Venison Creek Basin - 1968 to 1971 Data

Month (1968-71)	Average Precipitation* Thiessen-Polygon Weighted (in.)	Average Precipitation* Arithmetic (in.)	Standard Deviation S (in.)	Relative Standard Error E_r (%)
Jan.	2.58	3.07	1.36	21.8
Feb.	2.06	1.62	1.09	33.5
Mar.	2.25	2.27	0.72	15.8
Apr.	2.31	3.31	1.62	24.4
May	2.59	2.92	1.56	26.6
June	2.68	3.30	1.94	29.5
July	2.22	2.50	1.43	28.4
Aug.	2.28	2.14	1.44	33.5
Sept.	2.64	2.85	1.26	22.1
Oct.	3.01	3.51	1.58	22.5
Nov.	4.03	4.77	1.42	14.9
Dec.	3.96	3.96	1.53	19.4
Annual	35.00	35.90	5.12	7.2

* 4-station average

Table 9. Average, Standard Deviation and Relative Standard Error of Selected Daily Precipitation in Venison Creek Basin - 1968 to 1971 Data

Date - 1968	Average Daily Precipitation ($\bar{X} \geq 0.38$ in.)	Standard Deviation S (in.)	Relative Standard Error E_r (%)
Jan. 29	0.97	0.10	5.5
Feb. 1	0.53	0.08	7.8
Mar. 22	0.42	0.07	8.7
Apr. 23	0.62	0.20	16.1
May 9	0.55	0.13	12.1
May 16	0.58	0.10	8.9
May 19	0.38	0.07	9.4
June 29	0.41	0.18	22.1
July 5	0.47	0.41	43.5
Aug. 19	0.62	0.22	17.8
Sept. 1	0.41	0.12	16.4
Oct. 2	0.57	0.10	8.8
Oct. 18	0.86	0.12	7.7
Oct. 28	0.81	0.37	22.7
Nov. 9	0.41	0.16	21.6
Nov. 15	0.62	0.05	4.4
Dec. 4	0.55	0.03	2.9
Dec. 24	0.41	0.18	22.0

Table 9. (cont'd.) Average, Standard Deviation and Relative Standard Error of Selected Daily Precipitation in Venison Creek Basin - 1968 to 1971 Data

Date - 1969	Average Daily Precipitation ($\overline{X} \geq 0.38$ in.)	Standard Deviation S (in.)	Relative Standard Error E_r (%)
Jan. 17	0.95	0.15	8.0
Mar. 24	0.73	0.13	8.8
Apr. 1	0.62	0.20	15.9
Apr. 15	0.57	0.11	9.7
Apr. 17	0.73	0.43	29.4
Apr. 18	0.83	0.32	19.3
Apr. 21	0.53	0.23	22.5
May 7	0.71	0.13	9.5
May 10	0.71	0.04	2.8
June 15	0.55	0.06	5.7
July 4	0.73	0.15	10.2
July 10	0.62	0.63	51.5
July 18	0.56	0.27	23.6
July 26	0.57	0.23	20.6
July 27	0.58	0.13	10.9
July 28	0.59	0.13	11.5
Aug. 16	0.58	0.63	54.5
Sept. 16	0.59	0.08	6.5
Sept. 23	0.49	0.11	11.7
Oct. 2	0.38	0.08	10.6
Oct. 13	0.41	0.07	8.9
Oct. 21	0.53	0.04	3.9
Nov. 3	0.61	0.14	11.2
Nov. 4	0.39	0.20	26.2
Nov. 13	0.75	0.25	16.8
Nov. 15	0.42	0.18	21.4
Nov. 18	0.79	0.04	2.7
Dec. 10	0.88	0.09	5.1

Table 9. (cont'd.) Average, Standard Deviation and Relative Standard Error of Selected Daily Precipitation in Venison Creek Basin - 1968 to 1971 Data

Date - 1970	Average Daily Precipitation ($\bar{X} \geq 0.38$ in.)	Standard Deviation S (in.)	Relative Standard Error E_r (%)
Jan. 7	0.40	0.19	23.6
Jan.17	0.40	0.24	30.4
Mar.3	0.50	0.29	28.6
Mar.4	0.66	0.13	10.1
Mar.19	0.50	0.26	26.4
Mar.28	0.61	0.37	30.1
Apr.19	0.46	0.02	2.4
Apr.28	0.99	0.25	12.7
June 12	0.41	0.25	30.6
June 14	0.44	0.03	3.5
June 17	0.42	0.25	29.6
June 26	0.59	0.07	6.3
July 3	0.43	0.05	5.6
July 14	0.75	0.51	34.6
July 19	0.51	0.16	15.9
Sept. 2	0.49	0.15	15.8
Sept.8	0.43	0.25	29.3
Sept. 17	0.73	0.21	14.5
Sept. 26	0.58	0.23	19.9
Sept. 24	0.47	0.28	29.9
Oct. 2	0.48	0.18	18.5
Oct. 12	0.73	0.04	2.9
Oct. 22	0.75	0.57	38.2
Oct. 29	0.98	0.13	6.9
Oct. 30	0.45	0.04	4.7
Nov. 2	0.38	0.05	7.1
Nov. 9	0.44	0.05	6.2
Nov. 20	0.38	0.08	10.7
Nov. 23	0.40	0.26	33.3
Nov. 27	0.79	0.05	3.4
Dec. 3	0.71	0.23	16.5
Dec. 10	0.80	0.17	10.9
Dec. 11	0.53	0.16	15.1
Dec. 16	0.69	0.24	17.2
Dec. 26	0.40	0.08	9.5

Table 9. (cont'd.) Average, Standard Deviation and Relative Standard Error of Selected Daily Precipitation in Venison Creek Basin - 1968 to 1971 Data

Date - 1971	Average Daily Precipitation ($\overline{X} \geq 0.38$ in.)	Standard Deviation S (in.)	Relative Standard Error E_r(%)
Feb. 4	0.51	0.02	1.5
Feb. 8	0.48	0.04	3.7
Feb. 22	0.51	0.02	1.9
Mar. 6	0.42	0.12	14.3
Mar. 19	0.59	0.30	25.4
Apr. 1	0.71	0.12	8.5
Apr. 13	0.51	0.06	6.0
June 2	0.42	0.05	5.9
June 7	0.48	0.07	7.3
July 24	0.47	0.14	14.9
Aug. 10	0.81	0.27	16.7
Aug. 26	0.67	0.17	12.7
Sept. 20	0.70	0.09	5.9
Oct. 9	0.60	0.06	5.0
Nov. 20	0.51	0.20	19.6
Nov. 29	0.59	0.13	11.0
Dec. 30	0.41	0.42	52.0

Table 9. (cont'd.) Average, Standard Deviation and Relative Standard Error of Selected Daily Precipitation in Venison Creek Basin - 1968 to 1971 Data

Date - 1968-71	(2.0 in. < $\overline{X} \geq$ 1.00 in.) Average Daily Precipitation	Standard Deviation S (in.)	Relative Standard Error E_r (%)
Jan. 13/68	1.05	0.27	12.7
Apr. 3/68	1.09	0.09	4.2
Nov. 28/68	1.59	0.08	2.5
Dec. 27/68	1.03	0.47	23.1
Jan. 29/69	1.18	0.37	15.5
Jan. 30/69	1.01	0.09	4.5
Apr. 4/69	1.21	0.08	3.2
Nov. 1/69	1.38	0.09	3.2
Dec. 7/69	1.19	0.38	16.2
Apr. 1/70	1.12	0.49	22.2
Nov. 3/70	1.77	0.06	2.7
May 24/71	1.75	0.18	5.2
	($\overline{X} \geq$ 2.00 in.)		
June 25/68	3.76	0.09	1.2
Aug. 5/68	2.02	0.47	1.2
Sept. 5/68	2.72	0.35	6.5
May 18/69	2.20	0.23	5.3

Table 10a. Correlation Matrix of Monthly Precipitation Amounts for the Gauge Network in Venison Creek Drainage Basin; - 1968 to 1971 Data

	January				February				March			
	X_1	X_2	X_3	X_4	X_1	X_2	X_3	X_4	X_1	X_2	X_3	X_4
X_1	1.0 *				1.0				1.0			
X_2	0.933 *	1.0			0.901	1.0			0.826	1.0		
X_3	0.734	0.371	1.0		0.779	0.972	1.0		0.855	0.986	1.0	
X_4	0.978	0.859	0.702	1.0	0.788	0.968	0.995	1.0	0.171	0.402	0.299	1.0
	April				May				June			
X_1	1.0				1.0				1.0			
X_2	0.952	1.0			0.978	1.0			0.996	1.0		
X_3	0.924	0.987	1.0		0.991	0.997	1.0		0.986	0.990	1.0	
X_4	0.960	0.988	0.993	1.0	0.986	0.960	0.977	1.0	0.991	0.989	0.998	1.0
	July				August				September			
X_1	1.0				1.0				1.0			
X_2	0.750	1.0			0.952	1.0			0.952	1.0		
X_3	0.994	0.676	1.0		0.948	0.992	1.0		0.995	0.969	1.0	
X_4	0.930	0.456	0.964	1.0	0.851	0.849	0.909	1.0	0.964	0.845	0.934	1.0
	October				November				December			
X_1	1.0				1.0				1.0			
X_2	0.959	1.0			0.984	1.0			0.312	1.0		
X_3	0.969	0.960	1.0		0.991	0.990	1.0		0.626	0.167	1.0	
X_4	0.969	0.871	0.886	1.0	0.877	0.798	0.870	1.0	0.691	0.222	0.922	1.0

* correlation coefficient
X_1, X_2, X_3, X_4 - Langton, Mabee, Morston, Walsingham stations

Table 10b. Correlation Matrix of Annual Precipitation Amounts for the Gauge Network in Venison Creek Drainage Basin – 1968 to 1971 Data

Station	Langton (X_1)	Mabee (X_2)	Morston (X_3)	Walsingham (X_4)
	Correlation Coefficient, r			
X_1	1.0			
X_2	0.816	1.0		
X_3	0.900	0.982	1.0	
X_4	0.945	0.952	0.992	1.0

Table 11a. Regression Equations of Monthly Precipitation for the Gauge Network in Venison Creek Basin - Summer Period: (June - September)

Regression Equation	F-Value	R^2	S_e	t-Value
$X_2 = 0.24 + 0.87X_1$	74.9	0.84	0.55	8.7*
$X_2 = 0.35 + 0.51X_1 + 0.34X_3$	38.9	0.86	0.54	1.5, 1.1
$X_3 = -0.32 + 1.04X_1$	141.2	0.91	0.48	11.9*
$X_3 = -0.31 + 0.68X_1 + 0.35X_4$	125.5	0.95	0.37	5.2*, 3.3
$X_4 = -0.04 + 1.05X_1$	38.3	0.73	0.93	6.2*
$X_4 = 0.67 - 0.73X_2 + 1.61X_3$	59.9	0.90	0.58	6.8*, -2.8
$X_1 = 0.53 + 0.87X_3$	141.2	0.91	0.44	11.9*
$X_1 = 0.34 + 0.30X_2 + 0.63X_3$	78.6	0.92	0.41	1.5, 3.7

F-Value - variance ratio for the regression and deviations from the regression; based on the "Null Hypothesis" $\beta = 0$,

R^2 - coefficient of determination (proportion of variance explained by the regression),

S_e - standard error of estimate (in.),

t-Value - 'student-t' for test of significance of the regression coefficients.

* significant at 95% confidence level.

X_1, X_2, X_3, X_4 - Langton, Mabee, Morston, Walsingham station.

Table 11b. Regression Equations of Monthly Precipitation for the Gauge Network in Venison Creek Basin - Winter Period: (December, January - March)

Regression Equation	F-Value	R^2	S_e	t-Value
$X_2 = 0.57 + 0.76X_1$	31.6	0.68	0.70	5.6*
$X_2 = 0.44 + 0.43X_1 + 0.33X_3$	19.6	0.74	0.66	1.9, 1.8
$X_3 = 0.38 + 0.99X_1$	26.3	0.68	0.90	5.7*
$X_3 = 0.07 + 0.57X_1 + 0.55X_2$	20.0	0.74	0.84	2.0, 1.8
$X_4 = 0.72 + 0.80X_1$	26.7	0.64	0.80	5.2*
$X_4 = 0.58 + 0.44X_1 + 0.36X_3$	16.4	0.70	0.75	1.7, 1.7
$X_1 = 0.57 + 0.69X_3$	32.3	0.68	0.75	5.9
$X_1 = 0.24 + 0.48X_2 + 0.38X_3$	20.9	0.75	0.69	1.9, 2.0

Table 11c. Regression Equations of Monthly Precipitation for the Gauge Network in Venison Creek Basin - Pre-Season's Period: (April, May, October and November)

Regression Equation	F-Value	R^2	S_e	t-Value
$X_2 = 0.07 + 0.94X_1$	90.2	0.87	0.60	9.5*
$X_2 = -0.04 + 0.57X_1 + 0.37X_3$	45.5	0.87	0.60	1.5, 1.0
$X_3 = 0.29 + 0.99X_1$	201.3	0.94	0.42	14.2*
$X_3 = 0.28 + 0.81X_1 + 0.18X_2$	100.8	0.94	0.42	4.3*, 1.0
$X_4 = 0.36 + 0.94X_1$	116.4	0.89	0.53	10.8*
$X_4 = 0.35 + 0.82X_1 + 0.13X_2$	55.4	0.90	0.54	3.4, 0.5
$X_1 = -0.04 + 0.95X_3$	201.2	0.94	0.42	14.2*
$X_1 = -0.16 + 0.62X_3 + 0.37X_4$	143.8	0.96	0.35	4.4*, 2.6

Table 12. Correlation Coefficient of Monthly Precipitation for Independent Periods -- Venison Creek Basin

Month	Correlation Coefficient, (r*)		
	68/69	69/70	70/71
Jan.	0.644	0.379	0.541
Feb.	0.807	0.963	0.665
March	0.973	0.847	0.131
April	0.538	0.714	0.840
May	0.593	0.497	0.246
June	0.609	0.943	0.611
July	0.478	0.576	0.340
Aug.	0.731	0.863	0.842
Sept.	0.320	0.782	0.969
Oct.	0.986	0.556	0.611
Nov.	0.960	0.668	0.062
Dec.	0.957	0.289	0.358
Annual	0.631	0.453	0.242

Table 13. Regression of Relative Standard Error on Areal Average Precipitation for Various Data Groups and Accumulation Periods-Venison Creek Basin

Precipitation Data Group & Accumulation Period	Regression Equation	S_e (log unit)	F-Value	t-Value
Average Monthly[1] $\overline{X} \geq 0.01$ in.	$\log E_r(\%) = 1.05 - 0.5 \log \overline{X}$	0.278	9.1	-3.98
Average Monthly[2] $\overline{X} \geq 0.01$ in.	$\log RE_r(\%) = 0.70 - 0.41 \log \overline{X}$	0.341	3.5	-1.86
Average Daily[1] $\overline{X} \geq 1.0$ in.	$\log E_r(\%) = 1.00 - 1.5 \log \overline{X}$	0.339	8.3	-2.89
Average Daily[1] 0.38 in. $\leq \overline{X} < 1.0$ in.	$\log E_r(\%) = 1.00 - 0.41 \log \overline{X}$	0.344	1.8	-1.08

1 - based on standard error, $E_r(\%)$

2 - based on reduced standard error, $RE_r(\%)$

Table 14. Significant Statistics for Test of Difference Between Short-Term Basin Average Precipitation, $\overline{X}_B$, and Short-Term Regional Average Precipitation, $\overline{X}_R$

Month (1968-70)	Basin Precipitation[1] 3-Year Average $\overline{X}_B$ (in.)	Basin Precipitation[1] Standard Error of Average $S_{\overline{X}}$ (in.)	Regional Precipitation[2] 3-Year Average $\overline{X}_R$ (in.)	Regional Precipitation[2] Standard Error of Average $S_{\overline{X}}$ (in.)	t-Value
Jan.	3.58	0.317	3.13	0.268	1.09
Feb.	1.11	0.164	1.28	0.132	0.81
March	2.29	0.253	2.05	0.075	0.92
April	3.83	0.394	3.23	0.245	1.30
May	3.20	0.450	3.07	0.235	0.26
June	3.84	0.471	3.70	0.303	0.25
July	2.77	0.466	3.10	0.325	0.59
Aug.	1.92	0.425	1.84	0.290	0.02
Sept.	3.06	0.374	2.90	0.303	0.42
Oct.	4.03	0.390	3.35	0.155	1.61
Nov.	5.36	0.219	4.39	0.237	3.01*
Dec.	3.81	0.265	3.25	0.171	1.77
	38.81	0.605	35.33	0.796	3.46*

1 - Based on four basin-stations
2 - Based on eight regional long-term stations
* - Significant at 95% C.L.

Table 15. Significant Statistics for Test of Difference Between Short-Term and Long-Term Precipitation Averages

STATION - PRECIPITATION (IN.)

	Langton(X_1) (3-Years Avg. 1968-70)		Delhi-CDA (11-Years Avg. 1960-70)			St. Williams (11-Years Avg. 1960-70)			Tillsonburg (9-Years Avg. 1962-70)		
	$\bar{X}$	S	$\bar{X}$	S	t*	$\bar{X}$	S	t*	$\bar{X}$	S	t*
Jan.	3.54	1.39	2.34	1.23	1.34	2.90	1.44	0.69	2.81	0.98	0.97
Feb.	1.01	0.47	1.72	0.80	1.91**	2.19	1.01	2.80**	1.67	0.74	1.80
Mar.	2.01	0.18	2.63	1.20	1.58	2.97	1.22	2.40**	2.80	1.49	1.56
Apr.	3.59	1.55	3.56	1.35	0.03	3.73	1.56	0.14	3.42	1.28	0.172
May	3.39	1.89	2.61	1.30	0.67	2.66	0.97	0.65	2.21	1.13	1.02
June	3.75	2.14	3.02	1.63	0.55	3.02	1.36	0.56	2.75	1.54	0.75
July	2.59	1.33	2.75	1.17	0.19	2.28	1.35	0.35	2.58	1.22	0.012
Aug.	2.29	1.49	3.34	2.66	0.87	3.92	3.03	1.27	3.02	2.53	0.61
Sept.	3.06	1.57	2.48	1.38	0.58	2.88	1.78	0.16	2.97	1.32	0.09
Oct.	3.98	1.67	2.46	1.45	1.42	2.43	1.29	1.48	3.03	1.62	0.86
Nov.	5.24	0.69	3.34	1.38	3.20**	3.94	1.94	1.77	3.50	1.56	2.65**
Dec.	3.69	0.98	3.10	1.03	0.91	3.85	1.37	0.23	3.72	1.24	0.043
TOTAL	38.08	2.88	33.35	4.95	2.06	36.77	4.86	0.58	35.14	6.03	1.13

t* - t-ratio
** - significant at 95% C.L.

Table 16. Correlation Matrix of Annual Precipitation Amounts for the Main Station (Langton), Basin Mean and Two Groups of Regional Long-Term Index Stations

Stations	X_1	$\overline{X}_B$	Group-1 Stations			Group-2 Stations				
			SW	D	T	PD	B	W	L	PS
			Correlation Coefficient, r,							
Langton, X_1	1.000									
Basin Mean, $\overline{X}_B$	0.968	1.000								
St. William, SW	0.830	0.870	1.000							
Delhi, D	0.896	0.895	0.766	1.000						
Tillsonburg, T	0.903	0.913	0.719	0.940	1.000					
Port Dover, PD	0.880	0.874	0.789	0.830	0.825	1.000				
Brantford, B	0.708	0.717	0.648	0.759	0.729	0.794	1.000			
Woodstock, W	0.709	0.678	0.549	0.836	0.816	0.704	0.683	1.000		
London, A,L	0.820	0.781	0.629	0.851	0.877	0.712	0.576	0.857	1.000	
Port Stanley, PS	0.828	0.833	0.702	0.781	0.780	0.767	0.799	0.607	0.635	1.000

Table 17. Regression of Monthly Precipitation Amounts at Main Station (Langton X_1), Basin Mean ($\bar{X}_B$) with Group 1 Long-Term Stations (Tillsonburg, T, Delhi, D, St. Williams, SW) and the Three Most Correlated of Group 2 Long-Term Index Stations (Port Dover, PD, London-A, L, Port Stanley, PS); based on 1968, 1969 and 1970 Data

Regression Equation for: Main Station (Langton) X_1; Basin Mean $\bar{X}_B$	Significant Statistics for Partial Regression Coefficient						Multiple Correlation Coefficient R	F-Value	Cumulative Portion of Variance of X Reduced R^2	Standard Error of Estimate S_e (in.)
$X = a + \sum_{i=1}^{n} b_i X_i$	b_1 R^2	b_1 t	b_2 R^2	b_2 t	b_3 R^2	b_3 t				
$X_1 = -0.03 + 0.29T + 0.43D + 0.32SW$	0.815	1.33	0.019	2.26**	0.047	3.56*	0.939	78.78	0.881	0.565
$\bar{X}_B = -0.07 + 0.33T + 0.34D + 0.39SW$	0.834	1.81**	0.012	2.09**	0.070	5.18*	0.957	116.01	0.916	0.473
$X_1 = -0.36 + 0.44PD + 0.41L + 0.32PS$	0.774	3.90*	0.076	3.89*	0.035	3.14*	0.941	82.17	0.885	0.554
$\bar{X}_B = -0.20 + 0.46PD + 0.31L + 0.37PS$	0.765	3.72*	0.032	2.71	0.064	3.23*	0.928	65.92	0.861	0.608

R^2 = portion of variance of $\hat{X}_1$ or $\hat{\bar{X}}_B$ reduced

t = standard deviate

* = significant at 95% C.L.

**= significant at 90% C.L.

Table 18a. Frequency of Storm Duration for Grouped Summer Storms in Venison Creek Basin; based on 1968-1971 Data

Summer Period	Frequency of Storm Duration (hr.) (1-hr. increment class-interval)								Relative Frequency
	1	2	3	3-6	6-12	12-18	18-24	Total	
June	37	19	4	8	3	1	0	72	0.281
July	34	17	6	6	1	0	0	64	0.250
August	38	14	1	4	0	0	0	57	0.223
September	28	17	8	5	5	0	0	63	0.246
Total	137	67	19	23	9	1	0	256	1.00
Relative Frequency	0.535	0.262	0.074	0.090	0.035	0.004	0	1.00	

Table 18b. Frequency of Inter-Storm Interval (Dry Period) for Grouped Summer Storms in Venison Creek Basin; based on 1968-1971 Data

Inter-Storm Interval (1-hr.increment)	Frequency of Dry Periods - (summer period: June-Sept.)					
	1968	1969	1970	1971	Total	Relative Frequency
1 - 6	28	32	33	8	111	0.432
6 - 12	9	11	4	1	25	0.098
12 - 18	4	5	5	1	15	0.059
18 - 24	4	6	2	2	14	0.055
24 - 48	3	5	10	7	25	0.098
48 - 72	3	6	5	3	17	0.067
72 - 96	6	1	7	2	16	0.064
96 - 120	2	3	6	5	16	0.064
120 - 144	2	2	2	3	9	0.034
144 - 216	4	3	1	1	9	0.034
216 - 288	1	3	1	2	7	0.027
>288	1	0	0	1	2	0.008
	67	77	76	36	256	1.00

Table 18c. Frequency of Storm Intensity for Grouped Summer Storms in Venison Creek Basin; based on 1968-1971 Data

	Frequency of Storm Intensity class interval - in./hr.					
Summer Period	0.01-0.09	0.10-0.19	0.20-0.49	0.50-0.99	Total No. of Hours	Relative Frequency
June	124	23	10	4	161	0.310
July	97	17	10	1	125	0.240
August	61	11	7	6	85	0.164
September	116	21	10	2	149	0.286
Total	398	72	37	13	520	1.00
Relative Frequency	0.766	0.138	0.071	0.025	1.00	

Table 18d. Frequency of Duration and Depth for Grouped Summer Storms According to Arbitrarily Selected Storm Classes, in Venison Creek Basin; based on 1968-1971 Data

Storm Duration (1-hr. increment)	Number of Storms			
	Trace Storm (0.01-0.09 in.)	Moderate Storm (0.10-0.39 in.)	Large Storm ($\geq$0.40 in.)	All Storms
1	123	14	0	137
2	35	22	10	67
3	4	11	4	19
3 - 6	1	14	8	23
6 -12	0	2	7	9
12 -18	0	0	1	1
18 -24	0	0	0	0
Total	163	63	30	256
Relative Frequency	0.638	0.246	0.116	1.00

Table 19. Variability of Storm Intensity for Summer Storms with Total Depth ≥ 0.40 inch and/or Duration ≥ 3 hours in Venison Creek Basin

Date	Storm Duration (1-hour increment)	Total Depth (0.01 inch increment)	Max. - 1 hour Intensity (in./hr.)	Average Hourly Intensity (in./hr.)	Standard Deviation (in./hr.)
25/6/68	2	0.42	0.34	0.210	0.184
26/6/68	15	3.56	0.66	0.237	0.226
28/6/68	5	0.26	0.11	0.052	0.033
29/6/68	2	0.68	0.64	0.340	0.424
5/7/68	4	0.43	0.23	0.108	0.101
24/7/68	3	0.19	0.09	0.064	0.038
31/7/68	3	0.41	0.34	0.137	0.176
6/8/68	2	1.79	0.90	0.895	0.071
7/8/68	2	0.72	0.62	0.360	0.367
17/8/68	3	0.11	0.07	0.037	0.029
19/8/68	6	0.46	0.16	0.766	0.067
5/9/68	9	1.57	0.64	0.174	0.209
6/9/68	8	1.39	0.62	0.174	0.199
1/6/69	5	0.80	0.36	0.160	0.120
2/6/69	7	0.25	0.07	0.036	0.022
6/6/69	5	0.31	0.14	0.062	0.056
15/6/69	4	0.06	0.03	0.015	0.010
15/6/69	7	0.53	0.19	0.076	0.063
18/6/69	3	0.14	0.09	0.047	0.040
20/6/69	5	0.24	0.18	0.048	0.074
22/6/69	4	0.13	0.05	0.033	0.017
23/6/69	3	0.07	0.05	0.023	0.023
23/6/69	3	0.17	0.09	0.057	0.042
4/7/69	2	0.42	0.37	0.210	0.226
19/7/69	7	0.56	0.16	0.080	0.068
27/7/69	3	0.44	0.34	0.147	0.167
27/7/69	2	0.51	0.50	0.255	0.346
29/7/69	3	0.13	0.06	0.043	0.029
17/8/69	2	1.61	0.95	0.805	0.205
16/9/69	5	0.10	0.04	0.020	0.014
17/9/69	3	0.15	0.09	0.059	0.036
17/9/69	7	0.42	0.13	0.060	0.045
24/9/69	7	0.36	0.13	0.052	0.042
3/6/70	6	0.32	0.12	0.053	0.041
15/6/70	4	0.47	0.21	0.118	0.098
24/6/70	3	0.20	0.10	0.067	0.049
26/6/70	7	0.62	0.21	0.089	0.075
3/7/70	2	0.43	0.42	0.215	0.290
15/7/70	2	0.45	0.40	0.225	0.247
10/7/70	4	0.16	0.08	0.040	0.029
19/7/70	6	0.36	0.13	0.060	0.040
20/7/70	3	0.07	0.04	0.023	0.015
3/9/70	3	0.34	0.23	0.113	0.104
8/9/70	3	0.71	0.48	0.233	0.214
13/9/70	3	0.12	0.09	0.040	0.044
14/9/70	3	0.12	0.08	0.040	0.035
18/9/70	6	0.75	0.39	0.125	0.144
23/9/70	3	0.24	0.12	0.080	0.061
24/9/70	5	0.48	0.16	0.096	0.052
26/9/70	2	0.42	0.28	0.210	0.099

Table 19. (cont'd.) Variability of Storm Intensity for Summer Storms with Total Depth $\geq$ 0.40 inch and/or Duration $\geq$ 3 hours in Venison Creek Basin

Date	Storm Duration (1-hour increment)	Total Depth (0.01 inch increment)	Max. - 1 hour Intensity (in./hr.)	Average Hourly Intensity (in./hr.)	Standard Deviation (in./hr.)
5/7/71	6	0.29	0.09	0.048	0.033
17/7/71	5	0.26	0.10	0.052	0.045
24/7/71	3	0.43	0.20	0.143	0.081
24/7/71	6	0.36	0.10	0.060	0.032
10/8/71	6	1.04	0.39	0.173	0.157
22/8/71	2	1.10	0.97	0.550	0.594
25/8/71	4	0.26	0.11	0.065	0.042
26/8/71	5	0.79	0.56	0.158	0.052
13/9/71	6	0.36	0.12	0.060	0.044
19/9/71		0.12	0.05	0.030	0.023
20/9/71		0.74	0.18	0.106	0.068

Table 20. Correlation between Storm Parameters: Depth and Duration, $r_{X,T}$; Depth and Inter-Storm Interval, $r_{X,\tau}$; Duration and Inter-Storm Interval, $r_{T,\tau}$ - for Summer Storms in Venison Creek Basin

Summer Storms	Correlation Coefficient		
	$r_{X,T}$	$r_{X,\tau}$	$r_{T,\tau}$
1968 Storms	0.210	0.132	-0.162
1969 Storms	0.490	0.146	-0.181
1970 Storms	0.719	0.010	-0.173
1971 Storms	0.595	-0.199	-0.168
Large Storms	0.630	-	-
Moderate Storms	0.300	-	-
Storms ($X \geq 0.4$ in. and/or $T \geq 3$ hr.)	0.570	-	-